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Original facility design and site selection considerations are of great importance to the existence of confined animal feeding enterprises with a non-farm population which is encroaching at increasing rates into rural areas. Land use planning and zoning restrictions for agricultural/animal feeding purposes may well be the ultimate odor control tool of the future for newly instituted facilities. Extensive basic and applied research is required to provide adequate technology for use by existing facilities.

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CONTROL OF ANIMAL PRODUCTION ODORS:
THE STATE-OF-THE-ART

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FOREWORD

The Environmental Protection Agency was established to coordinate administration of the major Federal programs designed to protect the quality of our environment.

An important part of the Agency's endeavors to fulfill its mission involves the search for information about environmental problems, management techniques and new technologies through which optimum use of the nation's land and water resources can be assured. The primary and ultimate goal of these efforts is to protect the nation from the scourge of existing and potential pollution from all sources.

EPA's Office of Research and Development conducts this search through a nationwide network of research facilities.

As one of these facilities, the Robert S. Kerr Environmental Research Laboratory is responsible for the management of programs to: (a) investigate the nature, transport, fate and management of pollutants in groundwater; (b) develop and demonstrate methods for treating wastewaters with soil and other natural systems; (c) develop and demonstrate pollution control technologies for irrigation return flows; (d) develop and demonstrate pollution control technologies for animal production wastes; (e) develop and demonstrate technologies to prevent, control or abate pollution from the petroleum refining and petrochemical industries; and (f) develop and demonstrate technologies to manage pollution resulting from combinations of industrial wastewaters or industrial/municipal wastewaters.

This report is a contribution to the Agency's overall effort in fulfilling its mission to improve and protect the nation's environment for the benefit of the American public.

William C. Galegar

William C. Galegar, Director
Robert S. Kerr Environmental
Research Laboratory

ABSTRACT

Odors emanating from animal production facilities are the primary environmental cause for complaint resulting in great corrective expense and, in many instances, facility closure. The current state-of-the-art of odor control technology ranges from intensive waste management and good housekeeping practices to chemical treatment and facility isolation. These controls at best only limit the generation and/or quality of animal production odors. The most effective odor limiting technologies are the most cost intensive. Therefore, the methods used are dependent upon the seriousness of the situation and the cost-benefit that may be derived from their use.

Original facility design and site selection considerations are of great importance to the existence of confined animal feeding enterprises with a non-farm population which is encroaching at increasing rates into rural areas. Land use planning and zoning restrictions for agricultural/animal feeding purposes may well be the ultimate odor control tool of the future for newly instituted facilities. Extensive basic and applied research is required to provide adequate technology for use by existing facilities.

This report covers a period from July 1, 1977, to December 31, 1977, and work was completed as of December 31, 1977.

CONTENTS

Foreword iii
Abstract iv
Figures vi
Tables vii
British to Metric Unit Conversion viii
Acknowledgments ix

- 1. Introduction 1
- 2. Conclusions 4
- 3. Recommendations 6
- 4. The Air Pollution Problem 9
    - Noxious, Toxic, and Explosive Gases 9
    - Nutrient Transport 10
    - Dust 10
    - Maldorous Gases 11
- 5. Institutional and Societal Constraints 12
- 6. Odor Evaluation 16
    - Odor Composition 16
    - Odor Quality and Strength 19
    - Occurrence of Odors 19
    - Measurement of Odor Quality and Strength 19
- 7. Control of Nuisance Odors 25
    - Causes of Odors 25
    - Methods of Control 26
- 8. Summary 45

References 47
Appendix 59

FIGURES

Number Page

1 Relationship of Feeding Site to Population Centers, Wind Direction, and Odor Buffer Zone 27

2 Surface Wind Roses, Annual 29

3 Surface Wind Roses, July 30

TABLES

Number		Page
1	Livestock Wastes Characteristics	3
2	Percent of Feedlots in 13 Major Western Feeding States Receiving Pollution Complaints During 1973	11
3	Citation of Chemicals Identified as Volatiles from Cattle, Poultry, and Swine Wastes	17
4	Odor Threshold and Quality Description of Chemicals Considered to be Important to Organic Waste Odors	20
5	Methods Used to Collect Chemicals Volatilized from Animal Wastes	22
6	Gas Chromatographic and Other Methods of Analysis of Odors and Volatiles	23
7	Odorous Compounds Identified from the Atmosphere in a Beef Cattle Confinement Chamber Under Three Manure Handling Programs	32
8	Summary of Odor Intensities at 17 Texas Cattle Feedlots	32
9	Maximum Time of Total Hydrogen Sulfide Reduction in Liquid Dairy Wastes Treated with Hydrogen Peroxide	40
10	The Cost of Treating Liquid Manure for Odor Control	40
11	Quantity and Comparative Costs of Odor Control Chemicals Evaluated by Ulich and Ford	41

BRITISH TO METRIC UNIT CONVERSION

PRESSURE UNITS

1 pound per square inch (psi) = 70.308 grams per square centimeter (gr/cm^2)
1 inch of mercury (in. Hg) = 345.3 kilograms per square meter (kg/m^2)
1 inch (in.) = 2.54 centimeters (cm)
1 foot (ft.) = 0.305 meters (m)
1 mile (mi.) = 1.609 (kilometers (km)

VOLUME

1 cubic foot (ft^3) = 0.028 cubic meters (m^3)

AREA

1 square foot (ft^2) = 0.093 square meter (m^2)
1 acre (ac) = 0.405 hectares (ha)

WEIGHT

1 pound (lb) = 0.454 kilogram (kg)
1 ton (tn) = 0.907 metric ton (t)

WEIGHT PER UNIT OF AREA

tons per acres (tn/ac) = 2.240 metric tons per hectare (t/ha)
pounds per acres (lb/ac) = 1.121 kilograms per hectare (kg/ac)

CAPACITY

1 gallon (gal.) = 3.785 liters (l)

TEMPERATURE

Degrees Celsius (° C) = 5/9 (F-32) where F in temperature is degrees Fahrenheit

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SECTION 1

INTRODUCTION

Control and management of animal production odors is a relatively new problem faced by the redmeat and poultry and dairy product production industry. The need to manage and control odors was brought about by a revolution in animal production methods which in turn was stimulated by rapid population growth following World War II and more recently by a greater public awareness for the quality of the human environment. Prior to this revolution, these products were produced as secondary to cash field crops on small family farms. The numbers of animals raised were limited by the capabilities of the individual farmer and his family to care for the animals, raise all of the feed fed to the animals, and carry out the primary agricultural production activities of the farm.

By the mid 1950's, the family farms could no longer keep up with the increasing demands for animal products. The age of farm specialization was inevitable and the revolution of animal production methodology had begun. The poultry and dairy industry led the way. Chickens, both fryers and layers, were being raised in increasing numbers in very close caged confinement. Today it is not uncommon to find over a million birds in such facilities. Dairy cows were being maintained in large herds in resting barns and permitted to leave only for their daily milkings. Dairy herds now range in size from 50 to 2,000 head. In most cases these facilities were located near or adjacent to large metropolitan areas. This arrangement facilitated the timely and low cost distribution of the fresh products to the consumer.

In the early 1960's, the beef cattle and swine production industries followed the trend of the poultry and dairy industry. The swine industry was also being enclosed entirely within buildings. Swine facilities now include farrowing units, piggeries, and fattening units all within the same feedlot which may range in size from 50 to several thousand animals. The smaller operations may still be "out-of-doors"; however, the larger operations are totally enclosed and maintained under closely controlled and monitored hygienic conditions (1). The first phase beef cattle feedlots ranged in size from 500 to 10,000 head and were designed without regard for the environment. In some cases, these lots were located to take advantage of natural drainage to transport rainfall runoff and solid wastes from the pen surfaces. More modern designs include environment protecting considerations and range in capacity from a few hundred up to 150,000 head. The largest cattle feeder in the United States maintains two feedlots with a total capacity of over 250,000 head. Sheep feeding has not been of great importance until recently. Some sheep feedlots now have capacities of up to 20,000 head. Beef, swine, and sheep feedlots, unlike poultry and dairy facilities, are located in the vicinity of the feed producing areas. This is due to the comparative costs of transporting refrigerated meat versus the cost of transporting much larger volumes of feed to the animals. This trend toward such large capacity animal feeding facilities has greatly magnified the waste handling problem which includes aesthetic nuisances and hazardous conditions for human and animal health.

Estimates of the domestic livestock population in the United States in 1973 (2) were 61 million hogs, 17.7 million sheep, 11.6 million milk cows and heifers, 127.5 million chickens, 3.5 million turkeys, and 121.5 million beef cattle of which 14.4 million cattle were on feed. The population of beef cattle in 1950 (3) was 65.7 million of which 6.4 million were on feed. During this 23-year time span, the total number of cattle doubled and the percentage on feed increased from 6 to 12 percent. This large increase in total numbers of animals in such large concentrations has also greatly magnified the waste handling problem which includes aesthetics, nuisances, and animal and human health hazards.

Before the revolution in the animal production industry, the animals were raised on pastures where their wastes were dropped, broken down by natural processes, and assimilated into the soil providing nutrients and humus to condition the land. The large increases in total numbers of animals and the confinement of animals in such great concentrations has greatly magnified existing and created new wastes handling problems. The total production of wastes from all domestic livestock in the United States is about 2 billion tons* annually, of which approximately 50 percent is produced by large-scale confinement feeding operations (4). The amounts of manure produced by livestock (5) are presented in Table 1. Based on these characteristics a 950 pound steer will produce approximately 11 tons of manure annually. Expanding this figure to a 10,000 head capacity feedlot, there will be approximately 110,000 tons of manure to be disposed of annually or approximately 300 tons daily. A poultry farm with 100,000 turkeys produces 15 tons of wastes daily (4) and 270,000 laying hens generate an estimated 35-40 tons of manure on a daily basis (6). These manure wastes and those of sheep and swine produce offensive gases and odorants when wet and decomposing and disagreeable dust particles when dry.

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*English and metric units are used throughout this report as they were presented in the literatured surveyed. Conversion of units from one system to the other could lead, in some instances, to errors in interpretation as the data from which they were obtained is not in its entirety available to this author. Conversion factors are listed following the list of figures.

TABLE 1. LIVESTOCK WASTES CHARACTERISTICS* (5)

	Dairy Cattle	Beef Cattle	Poultry	Swine	Sheep
Animal weight (lb)	1,400	950	5	200	100
Manure Production (lb/day)	80.6	60	0.37	17	7
Moisture (%)	85	85	72	82	77

*Fresh mixed manure and urine.

According to Faith (7), there are two basic odors associated with feedlot wastes:

1. The natural aroma inherent of fresh excreta which is not persistent and dissipates rapidly as the excreta cools;

2. The offensive putrid odors of gases produced by the biological decomposition of excreta under anaerobic conditions (putrefaction).

The natural odor of fresh excreta is not of great concern as it is not a strong odor and is not offensive to most people. However, the odors produced by the anaerobic decomposition of manure wastes are of major concern. Every attempt should be made to control or eliminate the conditions which cause these odors.

The objectives of this paper are to determine the current state-of-the-art of production, measurement, and control of odors generated in concentrated animal feeding units, and to indicate broad areas of need and directions for future research such that current and long-range odor control research priorities may be established.

SECTION 2

CONCLUSIONS

The current state-of-the-art of odor control is indicative of a low level, low priority research effort which lacks a well organized and coordinated approach even though odor nuisance is the primary cause for pollution complaints resulting in legal actions against the industry. In spite of the level of organization, many alternative approaches to the problem have been investigated with varying degrees of success. Some generalized conclusions which may be drawn by summarizing the results obtained through individual efforts include:

1. Odor abatement after the odorants are produced and evolved into the atmosphere provide only temporary relief from the problem at great expense.
2. Odor production potentials in many instances can be significantly reduced during conceptual stages of facility planning by incorporating engineering designs into the facility which provide for maintenance of low moisture levels in the manure and ease of manure removal and management.
3. Judicious site selection can provide additional odor potential reduction plus a reduction of incidence of complaint should malodors periodically be formed.
4. Existing facilities may require extensive alteration to accomplish reduction in odor production.
5. Feedlot operators must conscientiously implement and maintain optimal odor reducing wastes, facility, and animal management practices.
6. Handling manure as a solid whenever feasible will reduce the volume of wastes to be handled, plus eliminate the need for cost intensive aeration and chemical treatment for odor control in slurry wastes.
7. Odor produced in liquid manure storage and runoff retention systems can, in many cases, be controlled by implementing proper lagoon loading rates and management practices when combined with aeration and chemical treatments prior to wastes removal.

8. Feed additives alter the characteristics of volatiles evolving from hog and cattle wastes; however, these changes, for the most part, are above the olfactory threshold for detection.

9. Chemical and biochemical agents added to the wastes provide limited success for odorant control in most cases. The agents which provide the greatest degree of success are, with few exceptions, the most cost intensive. Chemical and biochemical control, therefore, is considered an emergency measure to be used only until the cause of the problem is corrected.

10. The control of in-building odors has not been totally successful without the use of ventilation systems. The technology exists to control the release of odorants to the environment through such ventilation systems.

11. Dust has been shown to be a source of odors within confined areas and is suspect along with aerosols in the atmosphere surrounding outdoor facilities and lagoons. The mechanisms and interactions between odorants and dust and aerosols has not been demonstrated.

12. The interactions between two or more odorants upon mixing have not been adequately researched.

13. The interactions between odorants and other environmental factors and human responses to such interactions have not been adequately researched.

14. The technology to objectively evaluate the intensity and quality of odors does not exist. Current evaluation methodologies either utilize a totally subjective sensory approach or a combination of objective instrumentation correlated with subjective organoleptic techniques.

SECTION 3

RECOMMENDATIONS

Total suppression or control of odors from animal production facilities is not achieveable with current technology and economic constraints. The following principles, however, may be utilized to reduce the probability of complaints and odorant production potentials.

1. Select a site which is remote from neighbors and other potential sources of complaint, such as municipalities, schools, churches, and recreation areas. Sites with vegetative shelter can be used advantageously to hide the facility from the view of potential complainants and to disperse odors through wind turbulence caused by the existing vegetation.

2. Select a site on which orderly drainage can be established, thus reducing the moisture content of the wastes below that required for anaerobic microbial activity.

3. Utilize engineering design considerations which minimize the amount of moisture in the manure, manure storage system, and runoff collection facilities.

4. Remove and dispose of manure at regular intervals and dewater runoff retention facilities as rapidly following a runoff event as possible.

5. Practice good housekeeping principles avoiding excessive feed and waterer spillage; overcrowding animals causing muddy wet pens and animals; excessively large manure storage piles; unattended dead animal carcasses; and manure or mud-blocked alleyways and access roads.

6. Avoid lagoon overloading or unnecessary agitation of anaerobic lagoons. Utilize aeration techniques when problems occur and prior to sludge removal.

7. Consider chemical treatment of the manure pack and lagoons during periods of excessive odor production and prior to manure handling and disposal.

8. Judiciously select manure field spreading times to coincide with favorable weather conditions and periods when neighbors or recreating people are not likely to be near the area.

9. Install odor control equipment on building ventilation systems if persistent problems arise.

10. Establish a positive rapport with neighbors and community leaders. Show that you are interested in their view of your operation and that you desire to keep odors under control.

The current state of knowledge concerning the control of animal production odors evolves around a few basic common sense management principles which provide at best only remedial control. The results of most of the investigative research into the specific causes of odors, identification and interactions of various odorants, and physical and chemical control of odorants has been, for the most part, inconclusive or negative and frustrating. However, there have been some promising preliminary results which may lead to viable controls. Additionally, there are some research areas which have not been adequately explored by the animal production research community. Areas for future research in these categories include:

1. The development of a compendium of all existing odor control technology for all sources is essential to a well organized problem solving research approach. Few animal waste odor control research efforts have been based on technology developed and in use for odor sources other than animal production. This compendium should be world-wide in scope and include an evaluation of the potential of all existing and developmental processes for direct or adaptive use by the animal production industry.

2. A systematic comparison of sensory measurement methodologies should be carried out to develop a preferred or standard interim method for the measurement of odor intensity and quality in ambient air and at the source. This standard should minimize the current margin for variation in measurement of odor strength and variability caused by the use of current organoleptic techniques.

3. An organized comprehensive search for objective odor evaluation techniques for both source and ambient air should be initiated. Methodologies developed should eliminate the need for subjective sensory correlations with analytical instrumentation results.

4. There is evidence that animal production odors are related to dust and aerosols within enclosed animal production facilities and indications of similar relationships for open feeding situations. The mechanism and extent of this phenomenon is an important area for future research.

5. Alteration of the constituents in animal feed rations has in some preliminary studies shown promise. Further research is needed to determine the practicability of this approach; the scope of facility and species application; and the extent of control and/or volatile constituent alteration.

6. The interactions which occur upon mixing two or more odorants and the effect of interactions on the quality and strength of resulting odors should be investigated in an effort to locate and eliminate those volatiles which cause the objectionable and persistent qualities of odors.

7. Interactions between odor producing biological activity, odor perception, odor transport, and environmental variables such as, humidity, temperature, pH, and atmospheric pressure should be explored.

8. Psychological and annoyance reactions should be evaluated in feedlot exposure areas. These evaluations should include both positive and negative physiochemical and sensory responses.

9. Psychological interactions between animal waste odor perception and other environmental annoyances, such as, noise, dust, visual insult, irritants, and vibration should be evaluated.

10. The social and economic consequences of odor exposure should be identified and quantified. This should include studies of the impact of odor exposure on population shifts, property values, recreational activities in resort areas, and tourism.

11. The economics of odor prevention and abatement should be evaluated and documented. This should include appraisal of the costs of control versus the economics of impacts to arrive at cost-effective pollution control strategies.

12. The extent and transport of toxic substances in animal production odorants should be investigated.

SECTION 4

THE AIR POLLUTION PROBLEM

Air pollutants originating from animal production facilities may be divided into several classes according to their source. These include noxious, toxic, and explosive gases; nutrients; dust; and malodorous gases.

NOXIOUS, TOXIC, AND EXPLOSIVE GASES

The processes of anaerobic decomposition of highly organic manure wastes stored in lagoons, in pits beneath the floor of certain types of animal confinement facilities, and in covered or enclosed storage tanks produce gases which are often noxious or toxic to animals and humans or under enclosed conditions are explosive. Methane, carbon dioxide, carbon monoxide, ammonia, and hydrogen sulfide are gases evolved in the greatest concentrations from organic wastes (8) and considered to pose the greatest potential hazard to humans and animals (9, 10).

Under controlled conditions Drummond et al. (11) exposed lambs to gaseous ammonia at concentrations which are typically accumulated in totally enclosed slotted floor facilities over manure pits. The exposed lambs showed lower growth rates and exhibited profuse lacrimation, severe coughing and sneezing, and profuse nasal discharge which in some instances was bloody. Strombaugh, Teague, and Roller (12) reported similar effects of gaseous ammonia on pigs. Carbon monoxide and carbon dioxide have been considered hazardous to animals (9, 10). Carbon dioxide is not toxic; however, it can contribute to oxygen deficiency in improperly ventilated confinement facilities (13). Methane is not generally considered as toxic; however, large concentrations in poorly ventilated confinement areas can contribute to animal suffocation and create hazardous explosive conditions (9, 14).

Hydrogen sulfide is the most toxic of these potentially dangerous gases. Lillie (15) reports severe eye and respiratory tract irritation to humans exposed to concentrations of 20-150 ppm and adverse affects upon the nervous system with exposures of 500 ppm for 30 minutes. On several occasions swine were killed when manure stored in under floor pits was agitated or mixed before removal (15). This agitation released lethal concentrations of hydrogen sulfide into the swine buildings above. Since hydrogen sulfide does not collect in open feeding areas because of air dilution and oxidation to sulphur dioxide, potential acute toxicity of hydrogen sulfide is important only in confined feeding operations during agitation of anaerobic underhouse waste collection pits where house ventilation is poor (16).

A long list of incidents in which commercial livestock were injured or killed by gases which accumulate in animal confinement facilities has been compiled by Merkel (10). Gases accumulated in slotted floor hog barns with under slat manure pits caused workers to suffer from headache, shortness of breath, phlegm, congested nasal passages, dizziness, vomiting, and, in some instances, human deaths have been reported (9).

The production of these gases presents a real threat to animal and human health and property when permitted to accumulate to dangerous concentrations in confined areas. These areas include enclosed confinement facilities which are poorly ventilated and covered manure storage tanks. Even though these gases are generated in nearly every instance where manure is decomposing, they do not pose a threat in open or properly ventilated areas or in the exhaust air from ventilation systems as they are dispersed at concentrations well below those considered dangerous. This threat to health and safety affects only the animals and those who contact these gases during the course of routine work. The effects of this type of contact are considered as occupational diseases and therefore the concern of industrial hygiene and occupational medicine (17) and not an environmental issue.

NUTRIENT TRANSPORT

Ammonia nitrogen is the primary nutrient volatilized to the atmosphere from animal production facilities (18, 19). Hutchinson and Viets (20) reported that nitrogen enrichment of surface waters in the vicinity of animal feedlots and resulting algae and aquatic vegetative growths were due to ammonia volatization, atmospheric transport and subsequent rainout to and direct adsorption by surface waters.

Nutrient transport is an environmental problem which may be of great concern in localized areas. The control of odors will at the same time control most of the occurrences of nutrient transport because both problems are concerned with the evolution of gaseous ammonia. Therefore, odor control principles may be used to lessen the problem of nutrient transport.

DUST

Sweeten (21) reported that dust from cattle feedlot can constitute a localized nuisance during prolonged dry periods. Additionally, dust can pose a sanitation problem to neighbors, create traffic hazards, and in sufficient concentrations can also impair cattle growth performance and constitute an irritant to feedlot employees (21). Eby and Wilson (22) have implied that dust generated in poultry houses may be an odor transport mechanism. According to Burnett (23), dust in high intensity poultry houses transports odor and odorous compounds. Current odor transport research efforts at Iowa State University indicate that swine odors may be transported on dust or aerosols and that lagoon odors may be absorbed to and transported by ambient dust and aerosols (24).

The control of dust relates closely to the need for odor control in some instances and as a result of odor control practices in other situations.

Therefore, dust control will be discussed as appropriate with respect to those affected odor control practices.

MALODOROUS GASES

Emissions of malodorous gases from animal feeding enterprises can be inimical to the aesthetics and economics of a community. Personal discomfort, allergic responses, impaired respiration, loss of appetite, decreased liquid consumption, loss of sleep, mental stress, and nausea and vomiting have been incited by exposure to aesthetically unpleasant odors even though there is no apparent relationship between odors and a specific organic disease or toxicity of a gas (16). Court orders and the costs of litigation have forced some farmers out of business (25). Odor is the leading cause of pollution complaints in the State of Texas (26) and the thirteen major western feeding states (27, 28). Table 2 is a compilation of the percentage of feedlots receiving complaints by pollution type in the 13 major western feeding states during 1973 (27). A total of fifteen percent of the feedlots within the study area received pollution complaints. Seven percent of these were threatened with legal action and three percent actually experienced legal actions taken against them for permitting an odor nuisance (27). These statistics do not account for innumerable odor complaints received by city or county health departments. The numbers of complaints, legal suits, and unfavorable court decisions received because of odors by animal feeding operations in the humid high rainfall areas of the midwestern and southeastern states have not adequately been documented. The substantiality of this problem within these wet regions is predictable due to the wet climatic conditions and dense though dispersed human population. For these same reasons the problem also includes the smallest of production units in the midwest and southeast rather than just the one and two thousand head and larger units as in the western states where dryer climatic conditions and greater facility isolation from areas of human habitation prevail.

The persistence of the odorants emitted and the trend toward seeking legal relief from the effects of these odors by downwind neighbors and residents in all regions of the country isolate odors as the single most complained about, uncontrollable, and controversial air pollution problem associated with animal production.

TABLE 2. PERCENT OF FEEDLOTS IN 13 MAJOR WESTERN FEEDING STATES RECEIVING POLLUTION COMPLAINTS DURING 1973 (27)

Complaints of Pollution due to:	% of Feedlots
Surface water runoff	2.6
Contamination of groundwater	1.4
Feedlot odors	9.1
Dust	6.4
Insects	5.9
Noise	0.9

SECTION 5

INSTITUTIONAL AND SOCIETAL CONSTRAINTS

Odors emanating from animal production facilities have been labeled as a nuisance as early as 1611 (29), when an English court affirmed the granting of an injunction and damages to the plantiff upon a showing that the defendant had erected a "hogstye so near the house of the plaintiff that the air thereof was corrupted." More recently, increased public awareness and concern for environmental matters tend to promote the generally accepted assumption that corrective action must be taken whenever there is an objectionable smell. This has been over-magnified in the rural setting surrounding animal production facilities with the current population shifts of urbanites from the cities and suburbs into rural areas.

Specific human health hazards associated with gases which evolve from animal wastes are limited to situations in which persons encounter large concentrations of such gases (30). In addition to proven or suspected health hazards, attention must be paid to the annoyance reaction produced by air pollution. From the medical point of view, the term "annoyance" implies an effect which is not demonstrably pathogenic but involves a negative effect on the individual comfort and well being (31). However, the demarcation between pathogenic and annoying is not always distinct since the line between health and disease is partly established by current attitudes in the community. The World Health Organization (32) has defined health as "a state of complete physical, mental, and social well being and not merely the absence of disease or infirmity." Therefore, the presence of odors which interfere with the right of enjoyment of properties, homes, or established places of work or recreation may induce negative psychophysiological effects on exposed individuals. A person or persons subjected to objectionable odors have the right of complaint and in some instances may seek injunctive relief from such odors.

Technology does not exist which will allow for the quantitative determination of either the intensity of or an objective qualitative measurement of the "foulness" of an odor. The subjectivity of current odor evaluation technology makes the application of laws or regulations specifying numerical air quality standards for odorants impossible (33). Therefore, the legal constraints that are available to those who wish to be free from the annoyance of malodorous livestock enterprises are based primarily on the concept of nuisance.

Many state agencies (see Appendix) have based odor control regulations on the doctrine of nuisance. Some of these agencies have specified ambient odor concentrations based on the use of vapor dilution methodologies that determine the dilutions to threshold on a numerical standard. The desirability of the odor in these cases is still dependent upon individual preference and not an enforceable standard. Detailed discussions of Federal, state, and local regulations and the doctrine of nuisances as they apply to animal production odors have been presented by Recker (33), Prokop (34), Leonardos (35), and Sweeten and Levi (36). Whetstone et al. (37) have included a state by state summary of air pollution regulation pertinent to livestock odors in their discussion of the effects of pollution control legislation on the confined livestock production industry.

The following trends in odor nuisance lawsuits were summarized from Sweeten and Levi (38). The importance of good management was demonstrated in a 1972 County Circuit court decision in Michigan which declined to issue an injunction and grant substantial pecuniary damages against a swine operation. The judge indicated that the decision was based upon the facts that "the producer was using reasonable, commercially-accepted production methods; that no negligence was involved; and that, practically speaking, hogs cannot be produced in a completely odorless manner." Prior use was established by a 1972 Arizona Supreme Court decision and a 1973 Granbery, Texas jury decision. The Arizona case involved an urban development which was located near an existing feedlot. The feedlot owner openly admitted that his operation had an odor problem and that the odor was very evident in the vicinity of the urban development, but that the feedlot was in operation prior to the initiation of the development. The court ordered that the feedlot be moved for the rights and interest of the public and the developer was ordered to pay for the move since he had profited largely from bringing people to the nuisance.

A similar case in Texas was brought before a jury which ruled against an injunction and substantial monetary damages as the "social utilitarian value of feedlots outweighed the temporary inconvenience and annoyance of the newly-arrived residents." In another court case, odor intensity measured with a Barneby-Cheney Scentometer was used to close a feedlot which had operated for 15 years within the city limits of El Paso, Texas. The lot was closed as a permanent public nuisance by District Court Decree. A significant feature of the final judgement was the stipulation of a maximum permissible odor intensity of seven dilutions to threshold at the property line, as measured using the Barneby-Cheney Scentometer. Additional important court decisions both for public and private livestock odor nuisance actions have been briefed by Recker (33).

Totally avoiding nuisance complaints is for all practical purposes impossible due to the potential combinations of social and physiological background and the psychological interactions and individual preferences of those people which may live or recreate in areas which are affected by odors. The most important consideration may be the interaction of learning or experience and odor perception. Psychologists have repeatedly stressed the extent to which prior bias, either for or against an alleged odor source, can influence the emotional responses to an odor dosage (39). Thus, additional aesthetic insult from the odor source, whether in the form of other pollutants, or such factors as disorderliness or distasteful architecture may negate any positive community response from odor abatement attempts. Eugene (40) observed that the presence of visual cues, such as a smoke, in the case of an industrial setting, increases the frequency of reports of the perception of odor. It is not clear whether such results can be explained as evidence of biased responding or a keener odor perception because of sensory input from another modality and thus increased attention and awareness (41).

An actual feedlot odor complaint which was investigated by authorities in the State of Kansas supports the theory that a visible emission or source, because it is viewed as an odor contributor, does evoke negative emotional responses (42). During the final construction phases the feedlot operator and state authorities were receiving complaints of malodors. The feedlot had not been stocked with animals and therefore did not have any manure wastes to produce odors. The culprit was a truck stop washrack where cattle trucks had been washed down without odor complaint for a long period prior to the construction of the new lot. The knowledge that a new feedlot was being constructed and public fear of odor from the lot obviously increased awareness for and brought attention to that specific odor. Too many individuals think that the fact that something should smell bad or even looks like it should smell bad makes it so and therefore they smell foul odors. For these reasons, Giblin (29) states that courts must look at the entire picture on a case by case basis and cannot apply a strict standard to their decision. Additionally, it is important that the courts distinguish between "grudge-type" complaints and those which are legitimate.

George, Fulhage, and Mathews (43) lists several measures which can minimize legal troubles even though complaints cannot be completely avoided. These are summarized as follows:

1. Implement and use the best possible odor reducing management concepts and practices;

2. Respond promptly to complaints explaining your efforts to reduce odors and soliciting the complainants suggestions. Never give the impression that you do not care about their feelings or that you are not making every effort to abate odor pollution;

3. In selecting a site for a facility, avoid areas where odor potentials may be high and areas where there is good potential for urban development;

4. Maintain a clean neat appearing facility. Psychologically speaking if it looks clean it probably smells good also;

5. Locate manure runoff collection lagoons, manure treatment or storage lagoons, and solid manure storage areas out of the view of the general public. This is based on the premise that if you cannot see it there is nothing to smell;

6. Follow proper lagoon engineering designs and lagoon management practices; and

7. Empty and dispose of lagooned and solid wastes during optimal weather periods or periods of least neighborhood activity.

In summary, the problem of co-existence between the animal producer and society is exemplified by testimony for and against proposed odor regulations under consideration by the State of Iowa Department of Environmental Quality (DEQ) in 1976 (44). Proponents argued that they needed protection from objectionable odors while those who would be controlled by the regulation took the obvious stand against the control. One of the largest hog producers in the state, who was also a member of the DEQ, testified that odors were related to management and stated that he lived within 500 feet of his operation and lagoons and the he "didn't have any odor problems." Other proponents testified that it was impossible to operate a hog operation with lagoons without odors. Some of the blame for the problem rests on the overselling of odorless lagoons by producers to their neighbors. The producers, in all honesty, believe the odor level is acceptable. It probably is to them; however, to neighbors who live nearby the odor may be untenable.

Byrkett, Miller, and Taiganides (45) speculate that changes in cattle feeding technology, which may well be reflected throughout the animal production industry, may allow cattle and people to live in harmony and thus reduce the importance of the land use conflict consideration. Feedlots of the future may be a multi-story building that is completely enclosed and odor free with a total wastes recycling and/or composting operation. This type of facility may be no more obnoxious than a typical midwestern manufacturing plant and thus fit better with the structure of society in the population centers.

SECTION 6

ODOR EVALUATION

The evaluation of odors depends on the individual observers criteria for defining malodors and individual responses and sensitivity to odors. The sensations of sight or sound can be exactly defined because they can be measured, but this in the study of olfaction has, at present, not been accomplished (46). The chemical and physical characteristics of a compound responsible for an odor can be measured by standard or specially developed techniques, but this does not mean that these characteristics can be correlated with an organoleptic interpretation. The mental background of the person experiencing an odor determines their individual interpretation of the odor. A person with a pleasant memory of a particular smell, will classify this odor as pleasing, while another person with a different background, may take a conflicting view (46). Therefore, one may conclude that the effect of any specific odor on a population will be dependent upon the individuals within that population and their personal experiences. Thus, community reaction to an odor will vary and not be one which is readily predictable. The characteristics of odors also influence olfactory and psychophysiological responses and the processes of this evaluation. The primary characteristics of concern are composition, quality, strength and occurrence.

ODOR COMPOSITION

The chemical composition of the gases emitted by the decomposition of animal wastes have been evaluated for a variety of feeding situations. Over seventy chemical compounds have been identified, many of which contribute to the malodorous characteristics of the wastes (16, 30, 47, 48). Table 3, adapated from Mosier, Morrison, and Elmund (16), is a compilation of citations of chemicals identified as volatiles from cattle, poultry, and swine wastes by major chemical groupings.

The compounds which are most often considered as objectionable malodors are amines, mercaptans, sulfides, and disulfides (10, 16, 49). Elliott, Doran, and Travis (50) reported that trace amounts of organic acids, carbonyls, amines, indoles, skatoles, mercaptans, and alkyl sulfides can cause odors that are detectable for long distances. They further reported that at any given time, different intermediate odorous compounds may occur; thus, the perceived odor may be due to any combination of the compounds that are present. Approximately 40 percent of the volatiles on Table 3 are toxic substances listed for limitation in working environments by the

TABLE 3. CITATION OF CHEMICALS IDENTIFIED AS VOLATILES FROM CATTLE, POULTRY, AND SWINE WASTES

	Species		
Chemical	Cattle	Poultry	Swine
	-Bibliographic Reference-		
Alcohols			
Methanol*	52	-	53
Ethanol*	52	-	53
Hexanol	-	-	54
n-Propanol	55	-	53
Isopropanol*	-	-	53
n-Butanol	52	-	53,54
Isopentanol	-	-	53
2-Butanol	-	-	54
Sec-Butanol	-	-	54
Phenol	-	-	54
Et-phenol	-	-	54
P-cresol*	-	-	54
2-ethoxy-1-propanol	-	-	54
Carbonyl-containing			
Acetic Acid*	-	56,57	54
Benzoic Acid	-	-	54
Propionic Acid	-	56,57	54
n-Butyric Acid	58	56,57	54
Isobutyric Acid	-	57	-
n-Valeric Acid	-	57	54
Isovaleric Acid	-	57	-
Enanthic Acid	-	-	54
Caproic Acid	-	-	54
Benzaldehyde	-	-	54
Acetaldehyde*	52,55	-	59,53
Propionaldehyde	52	-	59,53
n-Butryaldehyde	-	-	59
Isobutryaldehyde	-	-	53
n-Valeraldehyde	-	-	53
n-Hexaldehyde	-	-	59
n-Octaldehyde	-	-	53
n-Decaldehyde	-	-	53
Ethylformate*	52	-	-
Methylacetate*	52	-	-
Isopropylacetate*	52	-	-
Isopropylpropioate	52	-	-
Isobutylacetate*	52	-	-
Acetone*	-	-	59,54
2-Butanone*	58	-	59
3-Pentanone*	-	-	59
2,3-Butanedione	-	-	54
3-Hydroxy-2-Butanone	-	-	-

(continued)

TABLE 3 (continued).

Chemical	Species		
	Cattle	Poultry	Swine
	-Bibliographic	Reference-	
Nitrogen-containing			
Methylamine*	60	-	-
Dimethylamine*	60	-	-
Trimethylamine*	55	-	54
Ethylamine*	60,55	-	61
Triethylamine*	-	-	61
n-Propylamine	60	-	-
Isopropylamine*	60	-	-
n-Butylamine*	60	-	-
n-Amylamine	60	-	-
3-Aminopyridine*	-	-	54
Ammonia*	60,62	57	59,53, 54,18
Indole	52	57	-
Skatole	52	57	-
Sulfur-containing			
Hydrogen sulfide*	63,52,64,	63,57	53,18
Carbonyl sulfide	63,64	-	-
Dimethyl sulfide	63,55	63,57	-
Carbon disulfide*	63	-	-
Dimethyl disulfide	63	63	54
Methanethiol*	63,65	63,57	-
Ethanethiol*	-	57	-
Propanethiol	-	57	-
Dimethyl trisulfide	-	-	54
Ketones			
Acetophenone	-	-	54
2-Octanone	-	-	54
Aromatic organics			
Toluene*	-	-	54
Xylene*	-	-	54
Aklyl benzene	-	-	54
Indane	-	-	54
Ringed organics			
Me-naphthalene	-	-	54
Simple organics			
CO_2*	64	53	58
Methane	64	53	58

* Listed for limitation in working Environment by Occupational Safety and Health Standards (51).

Occupational Safety and Health Standards of the National Institution of Occupational Safety and Health (51).

ODOR QUALITY AND STRENGTH

The quality of an odor is a subjective determination of the pleasantness of that odor to an individual or may be determined by comparing the odor to a similar odorant such as peppermint, rotten eggs, etc. Odor strength, on the other hand, is an objective determination of the number of dilutions with odor free air required to reduce a given amount of the odorous air to the concentration at which the odor is just detectable by the human olfactory systems or the threshold concentration. This is called the odor threshold number (OTN). Another measure of the odor intensity is the odor intensity index (OII), which is the number of times an odorant must be diluted by half with an odorfree medium to reach the odor threshold. Table 4, adapted from Mosier, Morrison, and Elmund (16), is a summary of the odor threshold and quality description of chemicals considered to be important to organic waste odors.

Changes in the intensity of an odorant may create a disagreement in observed odor quality. According to Lauren (46), hydrogen sulfide at concentrations sufficient to produce harmful physiological effects loses its smell of rotten eggs and produces a pleasant odorous sensation. Indole appears to be, at least psychophysiologically if not chemically, a combination of two odors (46). In low concentration it has the smell of jasmine and has a low threshold for perception. At high concentrations it has a strong odor of faeces and a-naphthylamine and a much higher threshold of perception. Observations of this type may be caused by changes in the receptor mechanisms of the human olfactory system with changes in intensity and duration of odorants. A comprehensive discussion of the human and animal olfactory system which may affect these changes has been presented by Miner (30).

OCCURRENCE OF ODORS

The occurrence of odors is defined as the duration or frequency that an odor exists and is expressed as having occurred at intervals for a given length of time with a given frequency during a known period of time (66). This concept is most useful in establishing guidelines for enforcement activities (36, 37).

MEASUREMENT OF ODOR AND STRENGTH

Current odor measurement techniques do not permit an accurate quantitative assessment of odor quality or odor intensity since the extremely sensitive human olfactory senses can detect and identify odors at levels far below the levels of sensitivity of the currently available instrumentation (30, 33, 34, 49). Rucker (33) has listed the following five basic approaches to odor measurement:

1. Identification of odorous gases (chromatographic).

TABLE 4. ODOR THRESHOLD AND QUALITY DESCRIPTION OF CHEMICALS CONSIDERED TO BE IMPORTANT TO ORGANIC WASTE ODORS

Chemical	Odor Threshold	Odor Description
	ppm	
	Carbonyl-containing	
Acetaldehyde	0.21 (67)	Green sweet (67)
Propionaldehyde	0.0095 (68)	*
3-Hydroxy-2-butanone	*	Butterlike (57)
Acetic acid	1.0 (67)	Vinegarlike (57), Sour (67)
Propionic acid	20.0 (68)	Pickle-like (57)
2-Methylpropionic acid	8.1 (68)	Sweat-like (57)
Butyric acid	0.001 (67)	Sour (67), Rancid (57)
	Nitrogen-containing	
Methylamine	0.021 (67)	Fishy (67), Ammoniacal (57)
Dimethylamine	0.047 (67)	Fishy (67)
Trimethylamine	0.00021 (67)	Fishy (67)
Ethylamine	*	Fishy (67)
Skatole	0.019 (68)	*
Ammonia	46.8 (67)	Ammoniacal (57, 68)
	Sulfur-containing	
Methanethiol	0.0021 (67)	Skunk (69), Foul (65)
Ethanethiol	0.001 (67)	Onion-like (57), Skunk (69)
Propanethiol	0.00074 (69)	Onion-like (57), Skunk (69)
t-Butylthiol	0.00009 (69)	*
Dimethyl sulfide	0.001 (67)	Rotten cabbage (69)
Diethyl sulfide	0.003 (69) 0.00047 (67)	Rotten cabbage (69)
Hydrogen sulfide	0.0072 (69) 0.072 (69)	Eggy sulfide (67), Foul (65)

* No data available

2. Measurement of odorant concentration (wet chemistry and correlation).

3. Measurement of odor intensity by vapor dilution (scentometer).

4. Measurement of odor intensity by liquid dilution (laboratory procedures).

5. Ranking of odor intensities by arbitrary offensiveness scales.

A summation of the methods of collecting chemicals volatilized from animal wastes and measuring odors and volatiles by gas chromatography and other analytical methods are presented in Tables 5 and 6, respectively. The use of chemical-trapping solutions are advantageous for the simplicity of operation and minimization of costs. Elliot, Doran, and Travis (50) reported that the limitations of such procedures for collecting odorous compounds include difficulties in achieving quantitative recoveries and problems associated with chemical alteration of the original odorous compounds. Gas chromatography is extremely useful for identifying odorous compounds; however, the method must be used with organoleptic techniques to characterize odor quality and intensity. Miner (18) has described a method of collecting gases volatilized from manure and other surfaces. His method utilizes a specially designed trap containing gas impinger tubes filled with absorption materials coupled with gas-liquid chromatography-mass spectral combination analysis. Recker (33) indicates that the main disadvantage of the gas chromatography and wet chemistry trapping methods is that they "merely identify the presence of odor-producing gases and measure their concentrations, but do not measure the intensity or quality of the odor."

Vapor dilution and liquid dilution are the two most popular methods of odor measurement (33). These methods are both organoleptic in nature and use the human nose as a detector. Prokop (34) presents a comparison of three vapor dilution methods of odor evaluation. These are the American Society for Testing Materials Syringe Method (78, 79), the Barneby-Cheney Scentometer (80), and the Dravnieks and Prokop Dynamic Forced-Choice Triangle Olfactometer (81). Results of these comparisons showed that the latter two methods were superior over the ASTM method but that the differences between the latter two methods were inconclusive. The advantage of the forced-choice over the scentometer method was the ability to determine a greater number of dilution ratios within the testing range. The scentometer method is selected for use most frequently in studies reported in the literature and is used as a standard odor measuring device on which odor limits are based in some states (35, 37). Detailed discussions of the instrument and its use in animal production situations have been presented by Miner (30, 48), Sweeten et al. (82), and Reddell and Sweeten (49). The liquid dilution method involves the use of odor panels to determine the dilutions to threshold and is the same method described for the determination of odor intensities in water supplies (83).

TABLE 5. METHODS USED TO COLLECT CHEMICALS VOLATILIZED FROM ANIMAL WASTES (16)

Chemical Group	Collection Method	Reference
Acids	Cryogenic collection in GLC column	57
	Manure extract	53
Alcohols	Propylene glycol trap	52,53
	Cryogenic collection	55
Aldehydes, esters, and ketones	Propylene glycol trap extracted with CCl_4	52,53
	Silica gel impregnated with dinitrophenyl-hydrazine	59
	Cryogenic collection	55,57
Amines	1.2N HCl trap	52,53
	0.01N H_2SO_4 trap	60
	5% acetic acid trap	61
Mercaptan and sulfides	$HgCl_2$ + $Hg(CN)_2$ traps	52,53
	Equilibrium vapor method	65
Nitrogen heterocyclics	Extraction and steam distillation of manure	57
All groups	Cryogenic collection	55,57
	Equilibrium vapor method	65

TABLE 6. GAS CHROMATOGRAPHIC AND OTHER METHODS OF ANALYSIS OF ODORS AND VOLATILES (16)

Chemical group for which analysis designed	Column	Detector	Reference
Acids	AW Chromosorb W + 10% SP-1200 + 1% H_3PO_4	FID	70
	AW Chromosorb W + 10% Carbowax 20M	FID	57
	Graphitized carbon + 0.5% H_3PO_4 + 3% PEG 20M	FID	71
Alcohols	Porapak Q	FID	53
Amines	Chromosorb 103 (injection port packed with Ascarite)	FID	60,72
	Gaschrom R + 28% Penwait 223 + 4% KOH	FID	60,72
	Anakrom SD + 10% Igepal CO 880	EC	60
	Graphitized carbon + 0.8% KOH + 5% PEG-20M	FID	71
	Chromosorb W + 10% amine 220 + 10% KOH	FID	73
Mercaptans and sulfides	Graphon + 0.5% H_3PO_4 + 0.3% Dexsil	FPD	74
	Chromosorb T + 12% Polyphenyl ether + 0.5% H_3PO_4	FPD	63
	Chromosorb G + 10% Triton X 305 + 0.5% H_3PO_4	FPD	75
Nitrogen heterocyclics	AW DMCS Chromosorb W + 5% SW-30	FID	57
Multigroup analysis	Chromosorb P + 10% Carbowax 20M AW-DMCS	FID	65
	Porasil S, C + Durapak-Carbowax 400	FID	55
	Other Analytical Methods		
Hydrogen sulfide	$AgNO_3$ impregnated filter paper, analyzed fluorometrically		76
	$Pb(O\ Ac)_2$ + 5% acetic acid impregnated filter paper analyzed spectrophotometrically		77

Limitations to and the disadvantages of the use of organoleptic odor evaluation techniques reported by Summer (84); Ludington, Sobel, and Gormel (85); Smith (86); Elliot, Doran, and Travis (50); and Miner (30) include:

1. Rapid saturation of the olfactory senses by some odor compounds.
2. Variation in sensitivity to different odors and previous experiences of individuals.
3. Variation in sensitivity of an individual to odors at various times of day or under various conditions of physical health.
4. Variation in sensitivity of an individual under varying conditions of mental attitude, stress, or momentary disposition.
5. Adaptation or adjustment of the observer to the stimulus.
6. Fatigue of the observer to a particular group of odors as a result of adaptation.
7. Admixing of odorants in which synergistic or antagonistic effects create changes in odor quality and/or strength.
8. Olfactory diseases such as anosmia (odor blindness) or parosmia (odor perversion).
9. Pungent odors causing irritation of the nerves in the nasal system.
10. Sample temperature.
11. Observer's age (sense of smell develops to about the age of 20 and begins to deteriorate after the age of 50).
12. Observer's sex (women are normally more sensitive than men to odors).
13. Habits of the observers such as smoking, wearing perfume or cologne, etc.
14. Climatic variables such as temperature, humidity, and wind velocities.

Considering the total spectra of disadvantages to organoleptic techniques, the currently available odor evaluation techniques are only cursory. The subjective nature of the data collected renders the establishment of equitable and enforceable odor limiting regulations and laws at best a very difficult task. Until objective technology is developed such that a large percentage of human bias can be eliminated from odor evaluation methodology, each odor problem will have to be evaluated on a case by case basis by both the animal producer and the enforcement agencies responsible for control.

SECTION 7

CONTROL OF NUISANCE ODORS

There are two basic approaches to reduce or control animal production odors. These are the prevention of odors from forming and the conditions which stimulate odor complaints at the source and treating the odor or the cause for complaint after they are established. A basic understanding of the causes of odors which ultimately lead to complaints is, however, essential to the accomplishment of these two basic approaches to the problem.

CAUSES OF ODORS

Anaerobic decomposition of animal wastes is the primary cause of odors. This occurs when the moisture content and/or degree of compaction are great enough to preclude atmospheric oxygen from the bacteriologically decomposing wastes. Moisture content of manure is related to porosity and other unknown factors. Above a 50 to 55 percent moisture content (wet basis) feedlot manure becomes anaerobic (87). White (88) indicates that anaerobic conditions persist in manures with sufficient moisture content which are stored for time periods greater than two or three days. Under these conditions, odorous volatile compounds are formed. However, if aerobic conditions exist, the volatile compounds produced do not have offensive odors (88).

Mielke and Mazurak (89) reported on the effects of manure compaction. The soil-manure interfacial layer reaches its maximum compacted density at 18 to 20 percent moisture content (wet basis). Temperature influences the rate of decomposition thus also exerts a significant influence on odor production (90). There is a ten-fold increase in anaerobic activity in the range of 5° to 35° C. Therefore, odor control efforts must be maximized during warm seasons. Miner (91) associated ammonia evolution rates from manure surfaces with temperature and humidity. The amount of ammonia evolved from an initially dry surface tripled following a rainy day.

The pH of animal wastes has an effect on the emission of volatile chemicals according to Mosier, Morrison, and Elmund (16). Odors produced from a solution of basic volatile compounds like amines, for example, will increase as the pH of the solution increases until a solution/atmosphere equilibrium is reached. Hashimoto and Ludington (92) developed equations to predict the rate of ammonia desorption from chicken manure slurries which demonstrate the effect of pH on ammonia volatility. Odor development in stored manure was studied by Gerrish (47). During anaerobic decomposition at a pH of 8, the pH of freshly excreted manure, the acetate, bicarbonate, and bisulfide ions remain in solution and do not contribute to odor. However, ammonia is evolved and wastes stored under these conditions will give off a distinctive odor of ammonia. Hydroxyl groups are used up as the reaction moves forward and the manure does not remain basic. As the manure becomes more acid, sulfides and acetic acid are given off in gaseous form creating an obnoxious odor. Odorless carbon dioxide is also evolved. Ammonia, under acid conditions, is in the ammonium ion form and tends to remain in solution. Other causes of animal production odors include spoilage of spilled feed; manure caked on animals; unattended or improperly disposed dead and decaying animals; and open silage storage and transport to the feed bunks (93, 94).

METHODS OF CONTROL

The control of odors and emissions from the large volumes of animal wastes and large scale manure storage and treatment facilities typical of the industry is according to Mosier, Morrison, and Elmund (16) "neither a simple nor a direct task." No economically and technically feasible solution has been found which is totally satisfactory (16). There are, however, several precautions, management practices, and artificial measures which may be applied to most feeding situations which could result in the reduction of malodors and potentials for odor complaints. For the purposes of this presentation, these will be grouped arbitrarily as follows:

Site Selection and Facility Design
Good "Housekeeping" Practices
Solid Manure Storage
Liquid Manure Storage and Runoff Retention Facilities
Manure Removal, Hauling, and Field Spreading
Altering the Ingredients of Feed Rations
Chemical and Biochemical Control Agents
Building Ventilation Systems
Dust Suppression
Ancillary Precautions

Site Selection and Facility Design Considerations

Site selection and facility design considerations can be used to reduce odor and potential odor complaints. Feeding facilities should be located remote from residential and commercial development (43, 95). Barth and Hill (96) suggest that the distance from residences should be a minimum of one-half mile and one mile from communities, schools, institutions, or places of employment and recreation. Locations should be selected which are downwind from such places considering prevailing warm weather winds. Preliminary results of a study to determine the separation distance required to adequately reduce feedlot odors to an acceptable level in Texas indicate that this distance may be as little as 0.4 km (0.25 mile) (97).

A buffer zone approximately the shape of an egg (Figure 1) has been suggested (98) to provide neighbors and communities protection from feeding facility odors. The orientation of the long axis is dependent upon the direction of the prevailing wind with the narrow end pointing toward the

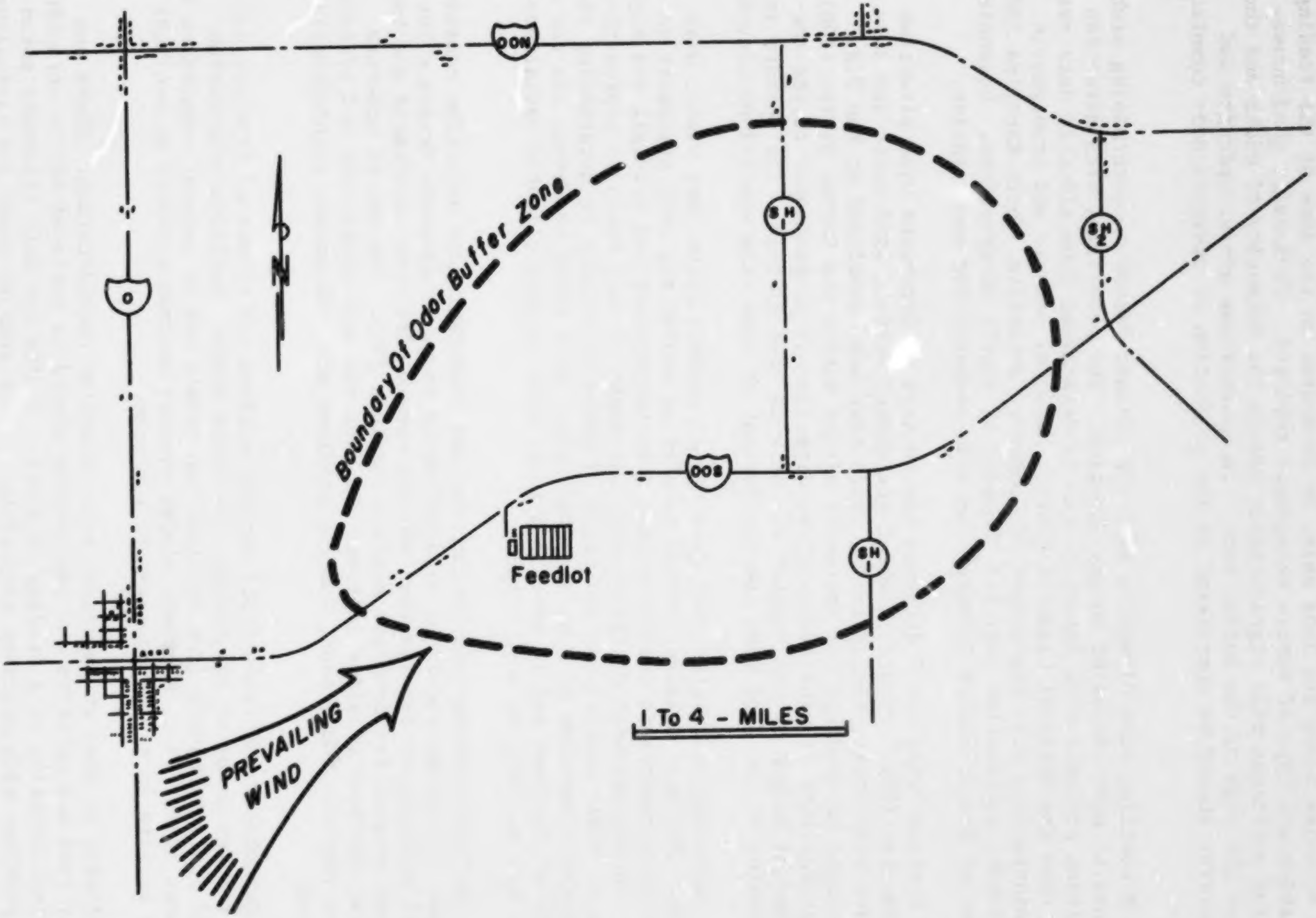

00N
0
N
Boundary Of Odor Buffer Zone
SH 1
SH 2
SH 1
00S
Feedlot
1 To 4 - MILES
PREVAILING WIND

Figure 1. Relationship of feeding site to population centers, wind direction, and odor buffer zone.

direction of the prevailing wind. The size of the buffer zone, usually from 4 to 20 miles along its long axis, is dependent on the size of the feeding operation and type of manure management employed. Obviously, good housekeeping practices will significantly reduce the intensity of odors and thus reduce the size of the buffer zone. In mountainous areas, updrafts and downdrafts should be considered in the prediction of possible odor complaints (98).

Prevailing wind direction is a significant factor in determining probable sources of odor complaint in any location. The prevailing wind direction and the least probable wind direction can be determined from climatic data available from the National Climatic Center, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, Asheville, North Carolina 28801. A separate publication entitled "Summary of Hourly Observations: Decennial Census of United States Climate" has been prepared for each station.

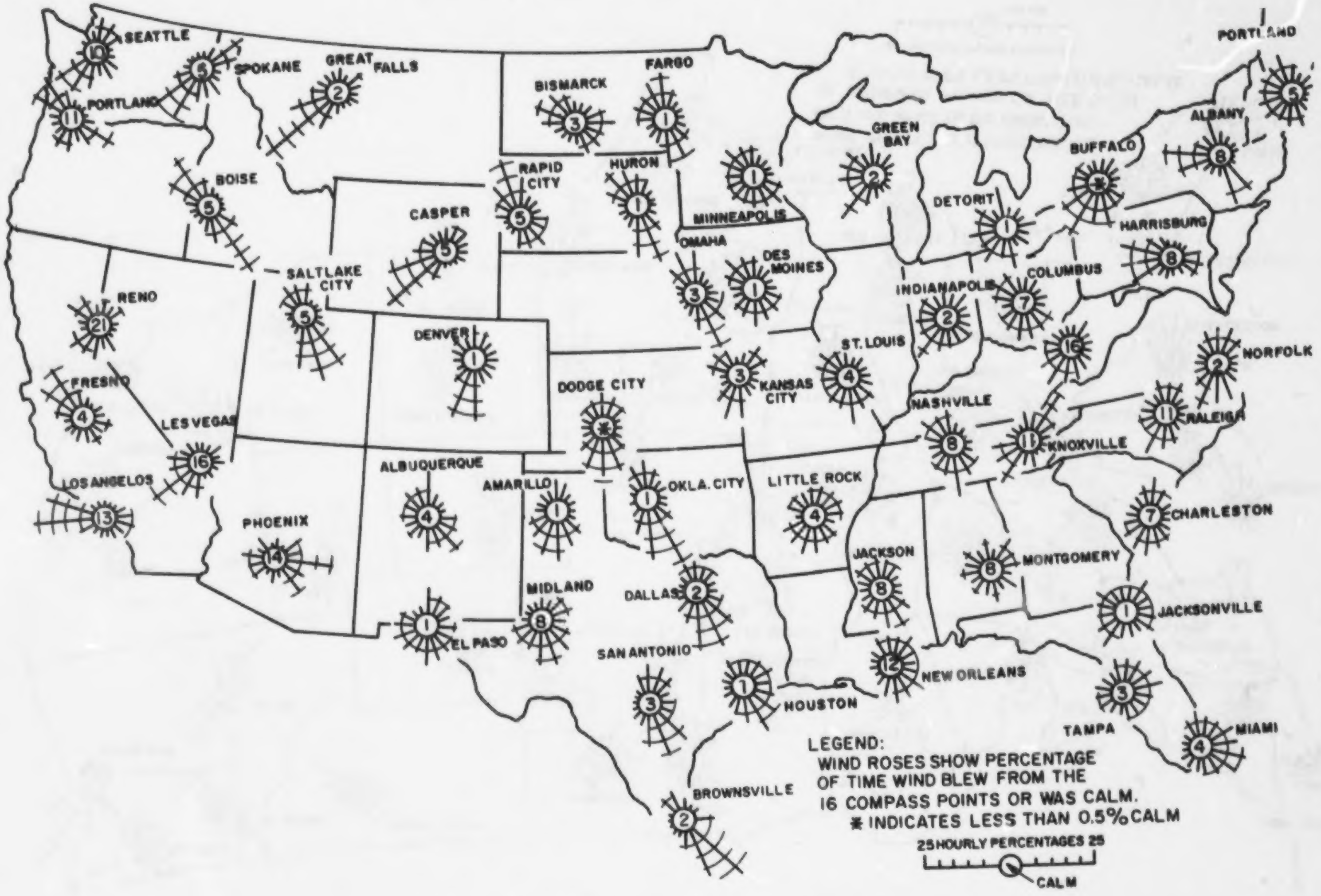
Surface "wind rose" diagrams may be used to determine wind direction frequencies (99). Figures 2 and 3 are annual surface wind roses and July surface wind roses, respectively, which have been developed by the U.S. Department of Commerce for the major cities within the United States (100). The probability of wind from a given direction is proportional to the corresponding length of the "spike" on the wind rose diagram. The numbers in the center of the wind rose are the percent of time calm conditions prevail.

According to Sweeten (99) directional probabilities vary widely with season. The most critical period insofar as minimizing odor transport to downwind receptors is during periods when temperature and rainfall are highest. Throughout most of the country the month of July would be representative of these conditions, and Figure 3 would be helpful in determining the appropriate location of a feeding facility. Wind roses are available for all months of the year and in some locations, with special climatic variations, other months would be more helpful.

Facility drainage and orientation are important site selection considerations. Locations should be selected where there is adequate drainage for runoff with slopes between four and six percent for open unsurfaced and two to four percent for concrete surface feedlots (96). The use of concrete feeding surfaces provides improved drainage and more convenient and efficient manure removal. Mud, odor, and fly problems are, therefore, significantly reduced.

Butchbaker and Paine (101) suggest uniform pen slopes of from one percent for dry areas to six percent for humid areas. Building orientation should protect animals from sunlight and permit use of natural vegetation to disperse odors (96). Southern slopes provide maximum exposure to sunlight which assists in drying open manure surfaces.

Zoning is also an important site selection consideration. State and county land use patterns and regulations should be reviewed before selecting the final location of a feeding facility. Zoning can help alleviate potential problems with nuisance complaints. If an area is zoned for agricultural purposes, presumably, animal feeding would be well within the limits of


SEATTLE
10
SPOKANE
5
PORTLAND
11
GREAT FALLS
2
BISMARCK
3
FARGO
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PORTLAND
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ALBANY
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GREEN BAY
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BUFFALO
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BOISE
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RAPID CITY
5
HURON
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MINNEAPOLIS
1
DETORIT
1
HARRISBURG
8
CASPER
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OMAHA
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DES MOINES
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SALTLAKE CITY
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RENO
21
INDIANAPOLIS
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COLUMBUS
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DENVER
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ST. LOUIS
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NORFOLK
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FRESNO
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DODGE CITY
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KANSAS CITY
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NASHVILLE
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KNOXVILLE
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RALEIGH
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LES VEGAS
16
LOS ANGELOS
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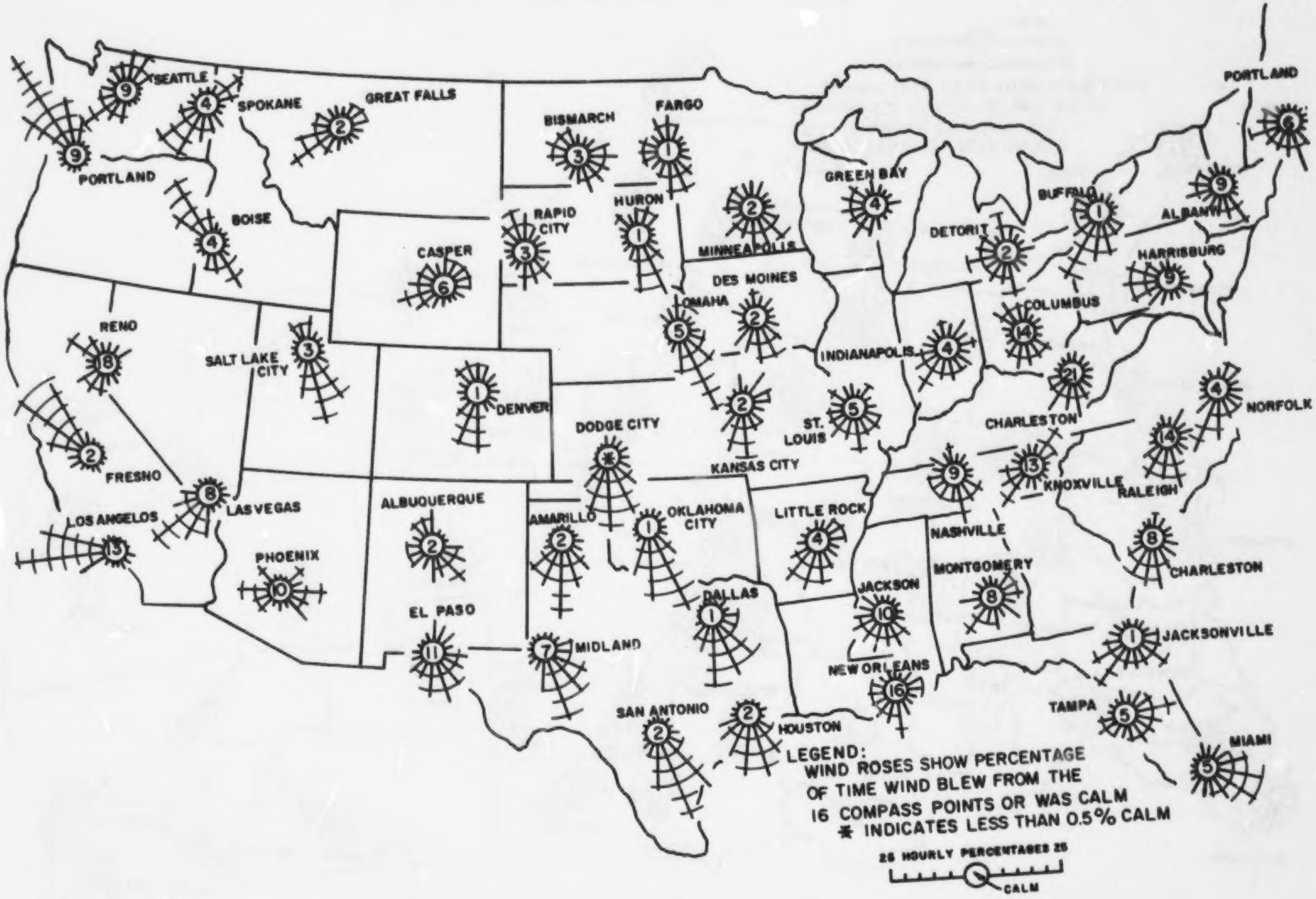
ALBUQUERQUE
4
AMARILLO
1
OKLA. CITY
1
LITTLE ROCK
4
CHARLESTON
7
PHOENIX
14
JACKSON
8
MONTGOMERY
8
MIDLAND
8
DALLAS
2
JACKSONVILLE
1
EL PASO
1
SAN ANTONIO
3
HOUSTON
1
NEW ORLEANS
12
TAMPA
3
MIAMI
4
BROWNSVILLE
2
LEGEND:
WIND ROSES SHOW PERCENTAGE
OF TIME WIND BLEW FROM THE
16 COMPASS POINTS OR WAS CALM.
* INDICATES LESS THAN 0.5% CALM
25 HOURLY PERCENTAGES 25
CALM

Figure 2. Surface wind roses, annual.


SEATTLE
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DETORIT
BUFFALO
ALBANY
PORTLAND
HARRISBURG
DES MOINES
OMAHA
COLUMBUS
INDIANAPOLIS
RENO
SALT LAKE CITY
DENVER
ST. LOUIS
KANSAS CITY
DODGE CITY
CHARLESTON
NORFOLK
FRESNO
KNOXVILLE
RALEIGH
LAS VEGAS
LOS ANGELOS
ALBUQUERQUE
AMARILLO
OKLAHOMA CITY
LITTLE ROCK
NASHVILLE
PHOENIX
MONTGOMERY
CHARLESTON
JACKSON
DALLAS
EL PASO
MIDLAND
JACKSONVILLE
NEW ORLEANS
TAMPA
SAN ANTONIO
HOUSTON
MIAMI
LEGEND:
WIND ROSES SHOW PERCENTAGE
OF TIME WIND BLEW FROM THE
16 COMPASS POINTS OR WAS CALM
* INDICATES LESS THAN 0.5% CALM
25 HOURLY PERCENTAGES 25
CALM

Figure 3. Surface wind roses, July.

approved land uses for that area. However, in many areas, communities and cities have control of agriculturally zoned lands which fall within a specified distance of their perimeter. Additionally, an animal producer does not have the right to cause damage to or degrade values of neighboring agricultural properties. In some areas, feeders are applying for zoning restrictions which will specify a strict agricultural type of use to discourage residential development or at least reduce the probability of legal actions from those who do establish residences in these zones (94). Thus, the primary use of zoning in this sense is to keep the number of neighbors at a minimum and to reduce the probability of having the facility declared a public nuisance. Advice offered to livestock feeders who can see suburbia approaching is to seek the restriction of land to agricultural uses by zoning and then watch eternally for the granting of exceptions and variances (25). George (43) recommends avoiding any site where there exists even a remote possibility of urban development or encroachment.

"Good housekeeping" practices can minimize odors and let neighbors know that concern exists about conserving a desirable environment (95). Frequent and thorough manure removal reduces odor production which, as stated previously, requires moisture and time (43, 96). Sweeten (28) recommends the following principles of good housekeeping for odor control. First, keep the manure relatively dry as much of the time as possible by adjusting animal stocking rates, maintaining good drainage, keeping manure solids out of runoff channels, settling basins, and retention ponds, and preventing overflow and leakage in animal watering and dust sprinkling systems. Secondly, keep a minimum quantity of manure and wastewater on hand. This may be accomplished by frequently collecting loose surface manure which absorbs precipitation and delays manure recovery efforts during wet periods; maintain an undisturbed manure pack approximately two inches thick just above the soil surface to seal off infiltration and promote rapid surface runoff; promptly clean drainage channels and settling basins; rapidly dewater runoff retention ponds; and backfill holes and low spots in the feedlot surface.

Bethea and Narayan (52) have demonstrated the effect of good housekeeping practices in a beef cattle confinement chamber. Organic volatiles were identified from the atmosphere in a chamber under three different manure management programs, Table 7. The value of daily manure removal and daily floor washing was clearly demonstrated by the reduction in the number of odorous gases.

The intensity of odors emanating from 17 Texas cattle feedlots as measured utilizing a scentometer instrument was reported by Sweeten and Reddell (87). These measurements suggested that moisture was the chief cause of elevated odor levels, Table 8.

These data indicate the necessity for maintaining good drainage in feed pens and the rapid dewatering of holding ponds. The lowest attainable odor intensity under dry lot conditions in Texas is seven dilutions to threshold permissible in most states with odor threshold standards (37). An additional advantage to dry manure conditions is the promotion of clean animals. The body heat of animals will accelerate bacterial decomposition of wet manure caked on animals and ultimately produce malodorous conditions (96).

TABLE 7. ODOROUS COMPOUNDS IDENTIFIED FROM THE ATMOSPHERE IN A BEEF CATTLE CONFINEMENT CHAMBER UNDER THREE MANURE HANDLING PROGRAMS (52)

Clean and Wash Daily	Shovel Out Daily	No Cleaning
Methanol	Methanol	Methanol
Acetaldehyde	Acetaldehyde	Acetaldehyde
Ethanol	Ethanol	Ethanol
Iso-Butyraldehyde	Ethyl formate	Ethyl formate
Ethyl formate	2-propanol	2-propanol
	Skatole	Skatole
	Indole	Indole
	Iso-butyl acetate	Iso-butyl acetate
		Propionaldehyde
		Methyl acetate
		Iso-propyl acetate
		Iso-propyl propionate

TABLE 8. SUMMARY OF ODOR INTENSITIES AT 17 TEXAS CATTLE FEEDLOTS, 1973-75 (87)

Location of Measurement	Condition	Dilutions to Threshold
Feedlot surface	dry	7
Feedlot surface	well-drained, moist	7-31
Feedlot surface	poorly drained, damp	31
Feedlot surface	wet, ponded	31-170
Runoff retention pond	--	31-170
Manure stockpile	--	7-170

Solid Manure Storage

Solid manure storage should be maintained aerobic so that the odorous gases of anaerobic decomposition are not produced. Manure stockpiles should be kept small as large piles of manure become anaerobic and odor problems exist when the manure is disturbed for removal and disposal (98). Aeration, as in composting, pH control, temperature control, and drying are expensive but usually effective (96).

Undercage drying and storage of poultry wastes can be accomplished at a cost of 0.6 cents and 0.007 cents per dozen eggs for forced air and fan drying, respectively (102). These methods do not, however, provide as efficient odor control as the more expensive aerated liquid undercage storage (102).

Sweeten and Reddell (87) suggest that the volume and duration of storage of stockpiled manure be limited and that the work "face" or surface of the pile be limited to as small an area as possible. This reduces the area of disturbance and the amount of surface from which odorous volatiles can escape to the atmospheres. Additional recommendations for stockpiling manure (103) include maintenance of moisture between 10 and 30 percent in the top six inches of the pile, locate the stockpile on a well drained area to assume rapid dewatering and utilize aerobic composting procedures. These include long manure windrows four to five feet in height and turn twice weekly for the first 30 days. Most feedlot operators, however, regard the extra handling required as too expensive.

Animals should be kept away from manure storage areas (96). Trampling of manure piles breaks the outer dried crust which forms and retains the volatile gases permitting them to escape to the atmosphere.

Liquid Wastes Storage and Runoff Rentention Facilities

Liquid wastes storage and runoff retention facilities include lagoons or ponds designed to provide some treatment and storage of animal wastes; manure storage pits and tanks; and runoff settling basins and retention ponds. Anaerobic decomposition of wastes in these facilities under a variety of circumstances can be a source of very undesirable odors. The control of odorants emitted from runoff retention and solids settling structures are a matter of good housekeeping of facility management and are discussed under that topic beginning on page 43.

Manure storage pits and tanks are usually covered with fixed or floating covers to prevent the escape of malodorous gases which were produced during storage. Manure is also stored in open pits, tanks, or anaerobic lagoons which, if undisturbed, scum over which effectively acts as a cover. In this situation odors are low level and localized in a small area and usually are not a problem (104). These wastes, in many instances, must be agitated before removal for land spreading and the disturbance of removal alone often releases odorous gases in such quantities as to cause odor complaints. Ritter, Collins, and Eastburn (104) suggest the use of certain chemicals during agitation which can deodorize the wastes before it is removed from the facility and disposed of by application to the land. These chemicals and their application are discussed under chemical control of odors beginning on page 55.

Jongebreur (105) suggests that odors from storage facilities may be prevented by aeration of the wastes before removal. Minimum suggested lagoon volumes for aeration are 500 liters per fattening pig, 1,000 liters per brood sow, and 30 liters per laying hen. Power requirements for floating surface aerators are 6 watts per fattening pig, 12 watts per brood sow, and 0.5 watt per laying hen. Good odor control results have been reported by utilizing aeration followed by direct injection into fallow and crop land.

Anaerobic lagoons provide an economical and convenient means of storing animal wastes. However, odors associated with this method of storage are by the nature of the anaerobic state a significant problem. Most of the problems associated with anaerobic lagoons are a result of overloading and improper management techniques. Overcash et al. (106) determined the treatment efficiencies and odor levels of simulated lagoons sized from 0.25 to 32 times the Soil Conservation Service (SCS) design standard of 0.8 cubic foot per pound of hog live weight. The overloaded lagoon gave poor pollutant removal efficiencies and highest odor levels. All other lagoon loadings gave 91 to 99 percent treatment efficiency in terms of chemical oxygen demand, organic carbon, and phosphorous removal.

Odor levels, as judged by panelists, decreased as lagoon capacity increased. Lagoons sized at two and four times the SCS standard loading rate produced lower odor levels than the lagoon loaded at the standard design rate. The odor threshold for anaerobic swine lagoons was determined to exist at approximately 3.3 to 6.6 cubic feet per pound of live weight served.

George, Fulhage, and Mathews (43) indicate that natural sun, wind, and wave action mix oxygen into the top few centimeters of water in a properly sized lagoon cutting off odors produced in the lower unoxygenated area. Thus, overloading lagoons precludes this phenomenon and odors are prevalent. Some additional recommendations for the management of an anaerobic lagoon to control odors include (43):

1. pump the lagoon half full of water before adding wastes;
2. start new lagoons during or before mid-summer as fall and winter starts do not permit adequate bacterial growth and overloading results due to manure accumulation;
3. lower salts and heavy metals by removing one fourth of lagoon volume and replacing with fresh water annually; and
4. feed the lagoon daily; never randomly slug load the lagoon.

Odor panels were used by Welsh et al. (107) to determine the effects of anaerobic digestion on the odor of swine manure. They concluded that anaerobic digestion brought about significant reduction in odor from swine manure digested 1) beyond 12 days solids retention time, 2) at 35° C, 3) with increased agitation of solids retention times less than 12 days, and 4) then stored for two to three months. The odor panel concluded: "although odors from anaerobically digested swine manure were considerably reduced in persistence and offensiveness, they were still identifiable as manure odors having negative qualities."

Roll, Day, and Jones (108) investigated the inoculation of anaerobic liquid swine manure with non-lagooned municipal digester sludge. Inoculation ratios of 2:1 and 1:1 manure to digester sludge exhibited the best chemical oxygen demand and volatile solids reduction. A panel of observers indicated the least offensive odor resulted from a dilution of 1:5 manure to digester sludge. The digester sludge established increased anaerobic activity in manure resulting in rapid degradation and odor control. However, the greatest degradation occurred in the digester with the most odor; therefore, it was concluded that "some odor may have to be tolerated in order to achieve optimal pollutant reduction."

Problems resulting from attempts to use anaerobic systems to store manure in a low odor manner stimulated researchers to evaluate methods of transferring oxygen into lagooned wastes to maintain aerobic conditions. Wastes treated under aerobic conditions are free of objectionable odors (95). Aerobic treatment systems include oxidation ditches, mechanically aerated lagoons, and oxidation ponds. Odors in lagoons can be reduced by mechanical aeration even in amounts well below those found necessary for wastes stabilization (109).

Oxidation ditches evaluated by Day and Jensen (110) and Converse and Day (111) provided adequate swine wastes odor control. Odors could be kept at a minimum if aeration was reduced so that no residual dissolved oxygen remained. This was achieved by maintaining the oxidation-reduction potential in the range of -300 to -400 MV and the pH in the range of 7.7 to 8.5. Power requirements of the mechanical aerators was reported as a major disadvantage of the methods. Parsons (112) suggests the use of sprinklers or floating aerators for odor control in overloaded poultry wastes storage ponds. An aerator that puts 50 to 90 pounds of O_2 daily into the pond is recommended for the waste from 10,000 hens. Dissolved oxygen levels must be maintained between one and two milligrams per liter to achieve adequate odor control (113). The costs of operating an oxidation ditch are approximately 89 cents per hog marketed or about 37 dollars per month (114). The possibility exists that this method may be adaptable to poultry wastes, but reservations are expressed for its value with beef cattle wastes (114).

A comparison of undercage oxidation ditches and diffused aeration, which is a forced air addition to a tank containing manure covered with water, of poultry wastes revealed a similar relative offensiveness of odors between the two systems (102). However, the offensiveness of the odors was approximately one-fourth that of undercage drying using forced air and fans. The costs per dozen of eggs for the oxidation ditch was 2 to 4 cents and 27 and 34 cents for the diffused aeration method. These were approximately 5 and 500 times the costs of forced air and fan drying, respectively.

An inexpensive apparatus for maintaining an aerobic, "nonsmelling layer" on top of lagoons or ponds which seals off odors produced in the anaerobic layer below has been described by George (115). The system is two-inch diameter pipe cross mounted on wooden and styrofoam floats. For a lagoon with a diameter of 100 feet a 50 foot pipe is used in each direction connected by a four-way pipe connector in the center. A series of 0.25 inch holes are drilled on either the right or left side of each arm to force the apparatus in one direction. The outer ends of three arms are capped. The fourth is attached to a hose through which lagoon water is pumped at a maintained delivery pressure of 14 psi which is adequate to prevent blocking of the holes by debris or bacteria. Total cost of the apparatus, including the pump, is approximately 300 dollars, with an operating cost of about 8 dollars per month for a 300-head hog farm.

Bell (116) in an evaluation of aeration of liquid poultry manure as a process for wastes stabilization and odor control concluded that "aeration must be considered as an odor control measure and not as a wastes stablization process."

Manure Removal, Hauling and Field Spreading

Manure removal, hauling and field spreading should be scheduled when climatic and soil conditions favor dispersion and dilution of odors. This usually is a matter of exercising good judgement. Odors from feedlot manures emitted during these activities are temporary and diminish with time (28).

The following considerations which may reduce odors or lessen the probability of odor complaint during manure handling and field spreading activities have been summarized from recommendations of Barth and Hill (96), Sweeten (28), and Sweeten and Reddell (87).

1. Avoid spreading manure near residences, highways or other places where people gather at times when they tend to congregate. Schedule spreading during periods when the wind will blow odors away from such areas.
2. Spread early in the day when air is warming and raising. Later in the day air is trapped and held lower to the ground by inversions. Additionally, most people who live in the cities arrive home between 5:00 and 6:00 p.m. and odors from manures spread during mid-day or late afternoon have not had adequate time to disperse.
3. Avoid spreading just prior to weekends and holidays when travelers are more likely to visit places that are unpopulated.
4. Soil absorbs and adsorbs odorous compounds. Incorporate spread manure by plowing or discing as soon after spreading as possible. Utilize injection methods to apply liquids to minimize odors and maximize nutrient conservation.
5. Spread only composted or surface scraped aerobic manures.
6. Use light-to-moderate application rates (10-30 tons/acre).
7. Consider the use of odor control chemicals to reduce odors in lagooned manures and wet feedlots manures before removal and disposal.
8. Spread on days when predicted wind speeds exceed five miles per hour. Utilize available weather information.

Huey et al. (66) reported on meterological effects on odor nuisance occurrence from a midwestern rendering plant. Odors were most persistent during the warmer summer months. Eighty-six percent of the complaints were filed during June, July, August, and September. The days of the week receiving the most complaints were Friday, Saturday, Sunday, and Monday, with Saturday receiving the most frequent complaints. The afternoon and evening hours were the worst hours of the day. Complaints increased as temperatures increased over 65° F and lessened above 90° F.

Very few complaints were received below the barometeric pressure of 28.84 inches of mercury; however, between 28.95 and 29.94 inches of mercury the number of complaints were 10-fold the complaints at 28.84 inches of mercury. Relative humdities below 70 percent caused more complaints than those over that percentage. Wind velocity, reportedly, had no significance.

These data were gathered so that parallels could be drawn. By watching meterological factors odor nuisance occurrences can be forecast with some degree of accuracy. The reseachers point out, however, that these results were obtained specifically for one meat rendering plant operation in one climatic/geographical area of the country, with specific sociological patterns; thus, care must be taken when drawing parallels with other types of industries.

Altering the Ingredients of Feed Rations

Altering the ingredients of feed rations can effect the quality of manure generated by livestock and subsequently the odors emitted by such wastes (48). An odor reduction in feedlot manure was reported in a Colorado study (117) as a result of the addition of sagebrush to the feed ration. Kellums (118) evaluated sagebrush and peppermint oil as feed ingredients to control odors. Addition of sagebrush to the ration at one percent and 1.5 percent levels had no detectable effect upon the subsequent olfactory evaluation of the fresh manure obtained from the treatments. The addition of peppermint oil at a rate of 0.25 percent of the ration significantly reduced the relative offensiveness that was associated with the fresh wastes. This modification was thought to be a masking effect directly related to compounds that were excreted in the urine and not associated with the feces. These results did not agree with those obtained with sagebrush in a Colorado study. However, these results may have been in agreement had the latter study carried the determination of effects on out from freshly excreted manure to the processes of putrefaction of these wastes.

The use of five percent charcoal by weight in a swine ration was found to significantly reduce manure odors (119). In the same study the following ration additives were less effective in controlling swine manure odors: lyophilized yeast, sagebrush, whole milk, "dry lacto" (*Lactobacillus acidophilus* culture), and wet lacto. A mixture of charcoal and wet lacto provided the best odor control. The additions of yeast and "dry lacto" dramatically reduced emissions of two important odorous gases, indole and skatole; however, odor panelists were unable to detect significant decreases in odor intensities.

Sweeten et al. (97) evaluated the use of calcium bentonite as an odor suppressant in feedlot rations. A two percent force feed bentonite ration, free choice bentonite, and a normal bentonite free ration was fed three groups of heifers. The force fed treatment gave lower odor levels compared to the other two diets evaluated. These researchers concluded that "calcium bentonite as a ration ingredient may have some benefit in reducing odors from a cattle feedlot and enhancing cattle performance during the first 21 days of feeding."

The effect of variation of the ratio of roughage to grain supplement in cattle was investigated by Kellems (118). Ammonia release rates were found to be three orders of magnitude greater than the rates of release of hydrogen sulfides in rations containing 25 percent roughage and 75 percent grain supplement. The rate of ammonia over hydrogen sulfide release increased an order of magnitude when the grain supplement was reduced to 50 percent of the ration. The changes in relative release rates of these odorants was thought to be due to changes in pH.

Another approach to the alteration of feed ingredients to control poultry waste odors has been suggested by Zindel (120). This approach is based on total recycle of poultry wastes back through the birds or to cattle. The manure wastes are dried to a product called DPW (dried poultry wastes). Rations containing 12.5 percent and 25 percent DPW have indicated that the practice is safe. The odor control theory is based on the hypothesis that where there are no wet wastes there are no odors; however, the elevated temperature drying unit may have to have an afterburner to eliminate the odors produced in drying.

Chemical and Biochemical Odor Controls

Chemical and biochemical odor controls may be categorized as the treatment of atmospheric odorants and the treatment of wastes to reduce odorant production. Treatment of atmospheric odorants emitted from animal production facilities are based in part on the following interactions which occur upon mixing two or more odorants.

1. Odor magnification where the odor intensity of the mixture is perceptually stronger than that of any component.

2. Odor cancellation where the intensity or negative qualities of one or both odorants are reduced.

3. Odor masking where one odor masks the others so that its odor dominates.

4. Odor synergism where one odor is made stronger in intensity or quality than it is by itself.

Paine (121) lists four main types of odor control agents which are based on these interactions in order of decreasing effectiveness.

1. Masking agents which usually are mixtures of aromatic oils which cover but do not reduce the odor.

2. Counteractants which neutralize the odor with aromatic oils leaving no overriding odor similar to the effects of odor cancellation.

3. Deodorants which are a mixture of chemicals that chemically destroy odors.

4. Digestive deodorants which are combinations of digestive enzymes and aerobic and anaerobic bacteria that eliminate odors through bio-chemical digestive processes.

Evaluation of the effectiveness of atmospheric odor control agents is accomplished using the matching standards technique as described by Paine (121).

Burnett and Dondero (122) evaluated these four agents and determined that masking agents and counteractants were the most effective. Young (123) found counteractants more successful than masking agents. The success of masking agents is limited, as the characteristic odor of the agents are considered malodorous by some people. Deodorization of three primary manure odorants methylamine, ammonia, and hydrogen sulfide with ozone was effectively demonstrated by Hill (124). However, the reaction rate was slower than reported by previous researchers.

Most evaluation results indicate that most of these agents are not effective to control odors and those that are effective are very costly (125, 126). Methods of controlling odors by preventing the production of odors should be exhausted before atmospheric odorant control is considered. In emergencies, however, Wilmore (126) indicates that "some products may prove to be worth what they cost."

The treatment of wastes to reduce or eliminate odorant production is based on the addition of chemicals or biochemical agents to the wastes which facilitate more orderly decomposition, reduce or inhibit decomposition, oxidize or otherwise alter the chemical composition of the volatiles, retain the volatiles in the manure pack, or absorb moisture required for anaerobic activity.

The evaluation of chlorine, lime, and paraformaldehyde as biological inhibitors; hydrated lime and sodium hydroxide for pH control; and potassium permanganate, hydrogen peroxide, and paraformaldehyde as oxidizing agents has been discussed in detail by Miner (30). The effectiveness of several odor control agents for controlling liquid dairy and swine manure was evaluated by Cole et al. (127, 128). Sodium hypochlorite, hydrogen peroxide, chlorine dioxide and potassium permanganate all of which are oxidants and powdered activated carbon which is an adsorbant were tested for short-term effectiveness. Dried bacteria, orthodichlorobenzene, formaldehyde, and sodium nitrate were tested for their long term effectiveness. None of the materials tested for either long or short term effectiveness were successful at controlling odors in liquid dairy manure. The materials tested for long term odor control in liquid swine manure were not effective in controlling odors or reducing hydrogen sulfide production. However, hydrogen peroxide, sodium hypochlorite, chlorine dioxide, and potassium permanganate dosed at 500 ppm greatly reduced sulfide and odor levels in liquid swine manure during the short term tests. Additionally, sodium nitrate was found to change the odor, reduce sulfide levels, and cause suspended solids to float for both swine and dairy manure.

Ritter, Collins, and Eastburn (104) determined the minimum amount of hydrogen peroxide required to deodorize liquid dairy wastes for removal and land spreading and evaluated 516 commercial chemical agents for control of odors in liquid swine and dairy manure. The results of the hydrogen perioxide are presented in Table 9. The hydrogen peroxide was effective to eliminate hydrogen sulfide in liquid dairy manure for a short period of time; however, other malodors associated with the wastes remained.

TABLE 9. MAXIMUM TIME OF TOTAL HYDROGEN SULFIDE REDUCTION IN LIQUID DAIRY WASTES TREATED WITH HYDROGEN PEROXIDE

Hydrogen Peroxide (ppm)	Maximum Time of Total Hydrogen Sulfide Reduction (minutes)
6.5	Not effective
12.5	60
25	90
50	90
100	120

Of the six additional chemicals evaluated, five are proprietary and of unreported content and the sixth was sodium hypochlorite. The proprietary chemicals with the trade names of Alamask 518B and 151A, Cairox and Agri-Gest appeared to be most effective in reducing total odorants. Cairox was found to be effective for approximately 72 hours. The treatment costs of all of the chemicals evaluated in this study are compared with costs of operating an oxidation ditch, Table 10.

TABLE 10. THE COST OF TREATING LIQUID MANURE FOR ODOR CONTROL (104)

Treatment	Level (ppm)	Cost per 10 cubic meters of wastes (dollars)
Hydrogen peroxide	12.5	0.06
Alamask 520A	100.0	5.07
Alamask 518B	100.0	3.30
Alamask 151A	100.0	12.12
Sodium hypochlorite	100.0	0.40
Cairox	240.0	3.33
Agri-Gest	24.0	3.04
Oxidation Ditch	-	13.98

The estimated costs of a single chemical treatment is less than that of the oxidation ditch. The costs of treating liquid manure with hydrogen perioxide at the 12.5 ppm level which is sufficient to control sulfides during waste removal and land spreading is less than treatment with any of the other chemical agents tested.

The cost of treating liquid swine manure with chlorine is very expensive according to Day and Jensen (110) even though it does effectively reduce odors. Their studies showed that pH adjustment with lime treatments effectively lowers sulfide emissions from liquid wastes. However, as may be anticipated, raising the pH increases ammonia release. In additional research, commercial odor control chemicals did not give satisfactory odor control when used in accordance with manufacturer's recommendations. Spraying enzymatic materials containing amylolytic, eclylolytic, proteolytic, and lypolytic enzymes on the surface of anaerobic lagoons was also unsuccessful.

Ulich and Ford (129) evaluated six chemicals for testing on beef cattle feedlot manure packs. The chemicals, selected on prior research and preliminary testing, were potassium permanganate, potassium nitrate, paraformaldehyde, a formulation of ortho-chlorobenzene marketed under a brand name as Ozene, hydrogen peroxide and a proprietary formulation known as Formula-2. The application rates and comparative costs of treatment for suppressing odors from feedlot surfaces and totally suppressing odors in beef cattle manure slurries is presented in Table 11. Potassium permanganate proved to be more effective in reducing odors than the other chemical/bio-chemical agents tested. The application rate of potassium permanganate to the feedlot manure surface was 20 pounds per acre sprayed on in a one percent solution in water. The order of presentation of the chemicals in Table 11 is in descending order of effectiveness of the compounds (130).

TABLE 11. QUANTITY AND COMPARATIVE COSTS OF ODOR CONTROL CHEMICALS EVALUATED BY ULICH AND FORD (129)

	Feedlot Surface		Total Odorant Reduction in Slurry	
Chemical	Quantity per acre	Cost per acre ($)	Quantity per ton of slurry	Cost per ton ($)
Potassium permanganate	20.0 lb	30.80	56 lb	86.24
Potassium nitrate	20.0 lb	30.80	***	***
Ozene	6.0 gal.	20.24	28.8 gal.	97.00
Paraformaldehyde	2178.0 lb	1078.11	197.0 lb	97.71
Hydrogen peroxide	12.4 gal.	30.84	19.3 gal.**	97.46
Formula-2	5.9 gal.	35.10	92.5 gal.	550.38

* Three percent concentration of hydrogen peroxide

** Ten percent concentration of hydrogen peroxide

*** Data not presented but relative expense indicated as much greater than for potassium permanganate

Miner (91) and Miner and Stroh (131) reported on the evaluation of the use of the odor control chemicals potassium permanganate; sodium bentonite; clinoptilolite and erionite zeolites; and five proprietary odor control products TNK (The Nose Knows), AGCO, Odor Control Plus, Micro-AID (LSSIO), and SANZYME on beef feedlot manure. The sodium bentonite, Odor Control Plus, and the two zeolites were found to consistently reduce the rate of ammonia release from the treated areas. Odor intensity measurements confirmed the effectiveness of sodium bentonite only. The Odor Control Plus treated pens had measurably less odors five days following treatment, but not ten. The cost of the effective materials ranged from 300 to 600 dollars per acre for treatment during the odor production season.

The costs of treatment with most of the materials and the effectiveness of each chemical control agent will vary with each individual set of circumstances. Therefore, careful evaluation of these circumstances should be considered before making the final decision to use chemical odor control agents, and then only after every possible management or good housekeeping alternative has been deployed unsuccessfully.

Building Ventilation Systems

Building ventilation systems should be controlled to prevent the exhaust of odorants to the atmosphere. Adequate ventilation is a major item in reducing the toxic and odorous gas and dust levels inside enclosed livestock shelters (95). Inside the facilities these gases and odorants are occupational hazards; however, when vented to the outside atmosphere, they become air pollutants and are a potential source of complaint.

The relationship between odors and particulate matter (dust) has been reported by Burnett (23). The odors carried in the air-stream of a swine facility located in Canada were removed by filtration (132). Dust particles collected in the filters were odorous. The particle size reported as responsible for transporting obnoxious odor qualities were the fraction between five and 20 microns. The odor removal effectiveness of the following four filtration systems were reported in order of descending efficiency.

1. Viscous impingement filter plus electrostatic preciptator plus activated carbon;

2. Viscous impingement filter;

3. Dry filter plus electrostatic precipitator; and

4. Dry filter.

Eby and Wilson (22) report that the removal of dust and odors from exhaust air is mechanically feasible by means of filtration. However, filter cleaning is impractical and one-time use of the filter is too expensive.

Norén (133) suggests that ventilation air be chemically treated before release. This can be done by adsorption, absorption, direct and catalytic combustion or by chemical destruction. Adsorption methods utilize beds or columns of activated carbon, silicagel, pethium chloride, or active aluminum. Dust clogging is the major problem with this approach. Absorption equipment consists of a tower through which air to be treated is drawn countercurrent to a stream of water which acts as a cleaning fluid. Good results have been obtained with the upper part of the tower filled with cellulose impregnated with phenol formaldehyde.

Combustion rapidly oxidizes the odorants in an open flame or by catalytic combustion at lower temperatures. Chemical oxidation can be accomplished by oxidizing the odorants by ozonation. All of these methods require considerable investment and/or operating costs. The most promising method according to Norén (133) is that of absorption.

Combustion of poultry manure drying odors has been proven effective in Great Britain (134). Jongebreur (105) has reported on the successful control of ventilation exhaust odors in the Netherlands through the application of biological air washers. Two types of air washers were described. These were air-water countercurrent and cross current scrubber designs. Water in the washers is recirculated until saturated with the odorant or aerosol. Efficiency of the scrubbers was increased by the addition of filler material with a surface area of 200 m^2/m^3. Then wash water was innoculated with activated sludge to promote bacterial growth on the filler material which then acted as a trickling filter in stabilizing the dissolved organic components of the exhaust air. Characteristic odorants in air were reduced by 60 to 80 percent. The costs of these scrubbers were relatively expensive. In swine feedlots the initial investment was equivalent to 22.72 dollars per pig capacity and operating costs were 2.28 dollars per finished pig. In poultry houses the initial investment was 1.81 dollars per laying hen capacity and the operating costs were 40 cents per hen per year.

The use of the oxidant ozone for removal of the odorants ammonia and methylamine from atmospheres in animal production facilities was investigated by Hill and Barth (135). Ozone was found to be an effective oxidant for both compounds; however, the long contact required raised questions as to the value of the use of the method inside production facilities. The atmosphere in such facilities contain many chemically active compounds which compete with the odorants for the ozone. The ozone would have to be present in the facility for an extended period. Physiological effects of ozone on the animals would prohibit such extended exposure. The ozone, however, could be used in the ventilation system to reduce the odorant quantities released to the outside atmosphere.

Dust Suppression

Dust suppression techniques utilized in open feedlot areas have not been adequately evaluated as to their effectiveness for reducing feedlot odors. In California research (136), peak dust generation occurred between 7:00 and 8:00 p.m. which coincides with experiences in Texas (21). Heavily concentrated dust laden air can then flow with little turbulent dispersion to nearby homes and communities. Carroll et al. (137) measured the effectiveness of sprinkling to control dust and the resultant effects on temperature and relative humidity. Sprinkling at a rate which reduces the dust characteristics of the atmosphere above the lot by 50 percent reduced the maximum temperature reached for the day by 10° F and raised the ambient relative humidity by not more than 10 percent. No deleterious effects on animal performance, morbidity or mortality were noted and no increase in fly or odor problems traceable to the sprinkling were observed. Chemical agents with demonstrated potential for dust control have shown little effectiveness in feedlots (136).

Ancillary Precautions

Ancillary precautions which may aid in reducing odors from or odor complaints against animal production facilities include:

1. Maintain an adequate cover crop of grass on cow-calf and backgrounding pastures (96). Manure will be distributed randomly and assimilated into the soil without turning anaerobic, thus minimizing odors.

2. Utilize existing and provide additional vegetative plantings for visual screening of facilities from neighbors and the general public (88, 96).

3. Practice rapid and proper disposal of dead animals (95, 96).

4. Collect wastewater from continuous overflow watering systems separately from rainfall runoff collection facilities. This overflow water is essentially unpolluted and creates wet conditions in runoff retention structures which stimulate odors (28).

5. Maintain an open line of communication with your neighbors and the public. Invite their comments and present your plans for odor abatement and significant future construction changes.

SECTION 8

SUMMARY

There are many site selection and facility design considerations; manure handling and storage options; facility, animal, and manure management practices; chemical control procedures; and ancillary precautions, which may be utilized to control and abate odors from animal production. Complete control may not be affordable or possible but odor reduction to acceptable levels is attainable and costly in most cases. Chemical controls are effective and usually very expensive and therefore should be considered as an emergency measure to permit adequate time to implement less costly and possibly more extensive long range changes in facility designs or management practices.

The State of Texas' Air Pollution Control Board has, as a requirement for obtaining construction and operating permits for feedlots, swine operations, and dairies, a list of primary special provisions which, for the most part, summarizes the best available odor control methodologies. These are stated as follows (138, 139, 140):

1. This permit allows for the construction of a _______________ having a total capacity of ____________head of ____________.

2. All dead animals must be disposed of properly within 48 hours after death.

3. Runoff water in the hol[illegible]ads must not become a source of obnoxious odors. It must be chemically or biologically treated or aerated, if necessary, to prevent nuisance conditions.

4. Excess moisture must be drained from pen areas to prevent ponding. Good pen drainage must be maintained at all times either by uniform slopes of 2-4 percent or by mounding of manure in flat pens.

5. When it becomes necessary to stockpile manure outside the pen area, the moisture content must be maintained between 10 and 30 percent (wet basis) in the top six inches of the pile, or it must be successfully demonstrated by the . . . [facility] operator that the stockpile is not a source of odors. The stockpile must be crowned with sloping sides and must be located in a well drained area to assure rapid dewatering.

6. Solid set sprinklers or portable spray equipment must be available and used as necessary to control dust.

7. Cleaning or scraping of pens and removal of manure from the stockpiles must be performed under favorable atmospheric conditions (wind direction must not be out of the _________, __________, or __________).

8. The operation of the __________ must be such as to prevent dust and odors from becoming a nuisance as determined by the Executive Director of the Texas Air Control Board.

Federal agencies have not established regulatory authority which is applicable to the control of odors emanating from animal production facilities. Additionally, the development, demonstration, and implementation of odor control technology has not been assigned an adequate level of priority by Federal agencies which fund research in this area. This situation exists in spite of the fact that odors are the number one environmental reason for complaint against animal feeding operations leading to litigation and court orders which ultimately lead to the closure of many facilities.

This attitude is reflected by Peters and Blackwood (141) in their source assessment of fugitive dust and atmospheric emissions of gases from beef cattle feedlots who concluded: "From the literature surveyed it is obvious that particulate, gaseous and odoriferous emissions from beef cattle feedlots can be controlled by conventional methods now available. These simple methods and procedures require an expenditure of managerial dedication and expertise as well as the monetary investment to purchase, install and maintain such systems." This conclusion is in direct conflict with the conclusions that this author can extract from the current literature. While it is true that animal production odor generation potentials can, in many cases, be reduced significantly by careful implementation of conventional methods now available, there are not any control technologies or combination of technologies which will guarantee that offensive odors will not be emitted by any open-air animal feeding operation. Those technologies which effectively limit the evolution of odorous gases from animal wastes are extremely costly and therefore not a feasible means of control. These considerations are concurrent with the conclusions of Mosier, Morrison, and Elmund (16) who state: "Unfortunately, the control of odors and emissions from large concentrations of organic waste is not simple and direct. No totally satisfactory solution has yet been found that is both economically and technologically feasible."

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APPENDIX

SUMMARY OF STATE AIR POLLUTION AND NUISANCE LAWS WHICH PERTAIN TO ANIMAL PRODUCTION ODOR CONTROL AND REGULATION (29)

ALABAMA

Key to Legal Citation
Ala. Code ____, ____.
(Title # - Section #)
(22-310)

AIR

The Air Pollution Control Commission (APCC) is the state agency responsible for implementing the state air pollution program [22-310(5)]. Air pollution is defined to include odors which do, or tend to, interfere with the enjoyment of life or property [22-310(3)]. The APCC can review all plans for new sources of air contaminants and deny permits if they are not in accord with the APCC's rules and regulations [22-310(8)]. There are no specific odor regulations in force. Odor problems are handled on a case-by-case basis after complaints have been received from the public.

ADDRESS: Air Pollution Control Commission
645 South McDonough Street
Montgomery, Alabama 36130
205/834-6770

NUISANCE

Public nuisances are broadly defined by statute to include such things as unsanitary premises, conducting a lawful business or trade in such a manner that it is likely to be a menace to the public health, and conducting an inherently unsanitary trade or business without complying with the regulations of the State Board of Health (22-75). Public nuisances are abated by county boards of health (22-76). The State Board also has inspection authority over all dairies and slaughter pens or houses (22-7). County boards are authorized to exercise special supervision over dairies and slaughterhouses (22-8).

ALASKA

Key to Legal Citation
Alaska Stat. §____
(Section #)
(46.03.020)

AIR

The Department of Environmental Conservation (DEC) is the regulatory body charged with the responsibility for controlling air pollution (46.03.020). It may enact regulations which can prevent, abate, or control air pollution (46.03.140). Air contaminants are defined to include odorous substances (46.03.900). Any municipality with a population in excess of 1,000 can establish and administer its own air pollution control program on an area-wide basis if the program is consistent with the state regulations (46.03.210). Each such program must be approved by DEC (46.03.210). If a local program is not being enforced properly, DEC may, after public hearing, step in and enforce the provisions of the local air pollution program (46.03.220). All emissions which are injurious to health or welfare are prohibited (46.03.140, 46.03.710, Reg. 18AAL50.110).

ADDRESS: Department of Environmental Conservation
Pouch O
Juneau, Alaska 99801
907/586-6721

NUISANCE

DEC is primarily responsible for the control of water, air and land nuisances (46.03.800-810). An air or land nuisance is defined as the placement upon any lot, street or premises of any garbage, offal, dead animals or any other matter which would be obnoxious (46.03.810).

ARIZONA

Key to Legal Citation
Arizona Rev. Stat. §____
(Section #)
(36-1706)

AIR

The Department of Health Services (DHS), Bureau of Air Quality is the state agency responsible for implementing the state's air pollution program (36-1706). The definition of an air contaminant includes odor (36-1701). DHS has opted to delegate its responsibility over feedlot odor problems to the Livestock Sanitary Board.

ADDRESS: Department of Health Services
Bureau of Air Quality
1740 West Adams
Phoenix, Arizona 85007
602/271-5306

NUISANCE

DHS has primary authority to enforce, investigate and abate all public nuisances (36-601). City and county boards of health are also empowered to abate such nuisances (36-602). Local boards of health can also enact sanitary regulations and can regulate feedlots (36-167) (Op. At-Gen 65-4). DHS also has the authority to investigate water, solid waste and air pollution that rises to the level of a nuisance (Reg. 9-8-432).

ARKANSAS

Key to Legal Citation
Ark. Stat. Ann. §____
(Title #-Section #)
(5-908)

AIR

The Department of Pollution Control and Ecology (DPCE) is the state agency responsible for implementing the state air pollution program (5-908). Air contaminants are broadly defined but do not specifically include odors (82-1933). Agricultural operations, including the growing or harvesting of crops, the raising of fowls or animals, and the use of equipment for agricultural purposes are specifically exempted from the air pollution control laws (82-1934).

ADDRESS: Department of Pollution Control and Ecology
Air Pollution Division
8001 National Drive
Little Rock, Arkansas 72209
501/371-1136

NUISANCE

The State Board of Health is given the authority to examine, investigate and abate nuisances (82-112). All cities and towns can cause any nuisance in their jurisdiction to be abated, and they may delegate that responsibility to the local Board of Health (19-2303).

CALIFORNIA

Key to Legal Citation
Cal.____ Code §____ (West)
[(Subject) Code §]
(Health & Safety §39013)

AIR

The State Air Resources Board (ARB) shares the responsibility for implementing an air pollution control program with county and regional Air Pollution Control Districts (APCD's). Air contaminant is so defined as to include odors (Health & Safety §39013). There is a general prohibition against the emission of any air contaminant which may cause injury or annoyance to persons or property (H & S §41700). This prohibition is not applicable, however, to odors emanating from agricultural operations necessary for the growing of crops or the raising of fowl or animals (H & S §41705).

ADDRESS: Air Resources Board
1709 11th Street
Sacramento, California 95814
914/322-6022

NUISANCE

The State Board of Health has general nuisance abatement powers (Health & Safety Code §203, 206). Nuisances and public nuisances are very broadly defined (Civil Code §3479). As noted above, these general nuisance statutes have been utilized to seek abatement of alleged noisome conditions arising from feedlot operation. City and County Boards of Health also have nuisance abatement authority (H & SC §41509).

COLORADO

Key to Legal Citation
Colo. Rev. Stat. §____
(§____)
(25-7-103)

AIR

The Department of Health (DOH), Air Pollution Control Commission (APCC) is the state agency reponsible for implementing the state's air pollution program (25-7-103). The definition of air contaminant does not specifically include odors but is broad enough to encompass odor problems (25-7-103). Regulations have been promulgated that deal with the odor pollution problem. The APCC uses the Barneby-Cheney scentometer to measure odor pollution. The dilution rate is set at 7 for residential and commercial areas and at 15 for all others. Agricultural sources are exempt, up to a dilution ratio of 127:1, if the best practicable treatment is being utilized to minimize emissions. Two odor measurements must be taken within one hour before enforcement is possible.

ADDRESS: Department of Health
Air Pollution Control Commission
4210 East 11th Street
Denver, Colorado 80220
303/388-6111

NUISANCE

DOH has the authority to abate nuisances (25-1-108). Pollution is classified as a Class 3 public nuisance (16-13-305). All local governments may prohibit nuisance type businesses up to one mile from their boundaries. They may also require sanitary standards to be maintained in any stable or pigsty. Finally, they can regulate livery stables within their borders (31-15-501).

CONNECTICUT

Key to Legal Citation
Conn. Gen. Stat. §____
(§____)
(19-507)

AIR

The Department of Environmental Protection (DEP) is the agency responsible for implementing the state's air polluion program (19-507). Air pollution is broadly defined by statute but odor is not specifically mentioned as an air pollutant (19-505). Odor is, however, included within the definition of an air pollutant in the regulations. Odor is not considered a serious problem at present. The basic regulatory scheme is that all new sources of air contaminants must obtain permits issued by the DEP (19-519a). Compliance with the statute and regulations is not a defense to a nuisance action.

ADDRESS: Department of Environmental Protection
State Office Building
Hartford, Connecticut 06115
203/566-3654

NUISANCE

All towns, cities or boroughs have the authority to abate public nuisances (7-148). Cities, towns or boroughs are also given the authority to define, within their limits, all nuisances and to provide for the abatement of such nuisances at the expense of the owner [7-194(29)]. They may also regulate and prohibit the keeping of swine, cattle or poultry within the city limits as well as prevent the construction of poultry pens and houses.

DELAWARE

Key to Legal Citation
Del. Code Title #, §____
(Title ____, §____)
(7-6002)

AIR

The Department of Natural Resources and Environmental Control (DNREC) is the state agency responsible for implementing the air pollution program (7-6002). Air contaminants are defined to include fumes or vapor, but not odor (7-6002). There are no fugitive dust or odor regulations applicable to the feedlot operator.

ADDRESS: Department of Natural Resources
and Environmental Control
Division of Environmental Control
Edward Tatnall Building
Dover, Delaware 19901
302/678-4791

NUISANCE

The State Board may investigate and abate all nuisances in the absence of a local board of health (16-126). Local boards of health may also abate all nuisances (16-310). They may order the removal of all hog pens if deemed necessary for protection of the public health (16-301).

FLORIDA

Key to Legal Citation
Fla. Stat. §____
(§____)
(403.031)

AIR

The Department of Environmental Regulation (DER), Air Quality Management Program is the agency responsible for implementing the state's air pollution program (403.031-2). Odors are not specifically included within the statutory definition of a "contaminant," but the definition is clearly broad enough to include them (403.301). The regulations define odors and objectionable odors utilizing a nuisance-type approach. No person may discharge emissions which contribute to an objectionable odor.

ADDRESS: Department of Environmental Regulation
2562 Executive Center Circle, East
Tallahassee, Florida 32301
904/488-6221

NUISANCE

The Department of Health, Division of Public Health and local public health agencies have the authority to regulate public health nuisances and sanitary practices relating to the disposal of excreta (381.031). The Division has no present regulatory scheme directly affecting feedlot disposal problems. Clearly, the Division of Public

Health has the ability on a case-by-case basis to abate nuisance-type conditions caused by unsanitary feedlot operations (386.01-02). Included within the statutory definition of nuisances injurious to health are odors of fly breeding conditions (386-401).

GEORGIA

Key to Legal Citation
Ga. Code §____
(§____)
(88-903)

AIR

The Department of Natural Resources (DNR) is the agency responsible for implementing the state's air pollution program (88-903). Odor is not listed as an air contaminant, but the definition of air pollution is broad enough to include it (88-902). In exercising authority under this section, DNR must consider the economic effect of the regulation as well as the amount of interference with the enjoyment of life (88-906). There are no regulations dealing with fugitive dust or odor problems.

ADDRESS: Department of Natural Resources
Environmental Protection Division
270 Washington Street, S.W.
Atlanta, Georgia 30334
404/656-4998

NUISANCE

The Department of Human Resources and county Boards of Health are empowered to exercise responsibility in matters pertaining to health not already exercised by another agency (88-204; 88-108). This would include nuisance abatement authority. Nuisances are broadly defined by statute (72-101).

HAWAII

Key to Legal Citation
Haw. Rev. Stat. §____
(§____)
(342-22)

AIR

The Department of Health (DOH) is the agency responsible for implementing the state's air pollution program (342-22). Air pollution is defined to include both odors and dust (342-21). Odors are defined by regulation to include smells which are "unpleasant to persons," which "interfere with sleep," or are otherwise detrimental to health. Any new source of air pollution must receive a permit prior to construction and operation. There are no specific odor regulations.

ADDRESS: Department of Health
Environmental Health Division
P. O. Box 3378
Honolulu, Hawaii 96801

NUISANCE

The DOH also has general nuisance and sanitation regulatory powers. DOH and county health departments have the affirmative duty to enforce all DOH regulations; this includes the power to regulate nuisances, adulterated food, pig and duck ranches, and any place where a noxious business may take place (322-1). Counties have licensing authority to regulate the location of any building in which a noisome trade is carried on (322-42). This is under the aegis of the county board of health (322-42). All licensees must maintain the premises in a sanitary condition (322-42). DOH has enacted regulations dealing with livestock and poultry raising operations. The regulations require all manure to be promptly removed (within 24 hours) in order to avoid fly and rodent infestation and odor problems. Manure may be placed in licensed sanitary landfills. The regulations also deal with the construction, location, and maintenance of feedlot operations, including a general requirement that the enclosures must be kept free from accumulations of excreta.

IDAHO

Key to Legal Citation
Idaho Code §____
(§____)
(39-105)

AIR

The Department of Health and Welfare (DHW) is the agency responsible for implementing the state's air pollution program (39-105). Air contaminants are defined to include dust, fumes, vapors and other gaseous fluids, but there is no mention of odors (39-103). The DHW regulations, however, include odor as an air contaminant. The regulations require that odor emissions be minimized so as to not cause air pollution. In practice DHW has handled odor complaints on a case-by-case basis, while encouraging local governments to zone and plan effectively to avoid the problem.

ADDRESS: Department of Health and Welfare
Environmental Protection Division
State House
Boise, Idaho 83720
208/384-2390

NUISANCE

Nuisances include anything which is injurious to health or offensive to the senses (52-101). Nuisances can be abated by either a private or public legal action (52-302-3). District boards of health have the authority to preserve and protect the public health (39-414). Cities may also establish boards of health to operate within the city and up to five miles outside the city boundaries (50-304). Cities may define nuisances and abate them within an area extending three miles beyond the municipal boundaries (5-334).

ILLINOIS

Key to Legal Citation
Ill. Rev. Stat. (Ch____, §____)
(Ch____-§____)
(111 1/2-1004)

AIR

The Illinois Environmental Protection Agency (IEPA) is charged with the duty of collecting and disseminating all pollution control information and of monitoring and ascertaining the quantity, quality, and nature of all discharges from any contaminant source (air, water, and land) (111 1/2-1004). It also administers the permit system and reviews all plans and specifications for construction (111 1/2-1004). The Pollution Control Board (PCB) has two primary functions: rule-making and enforcement (111 1/2-1005). Before it can exercise any rule-making authority, however, the third branch of the environmental organization must prepare a complete economic impact analysis of the proposed rules (111 1/2-1006). This organization is called the Institute for Environmental Quality (IEQ).

The PCB, IEPA, and IEQ are all responsible for the air pollution program (111 1/2-1004). The definitions of air pollution and air contaminants include odors (111 1/2-1003). As seen earlier, the IEPA recognizes the air pollution in terms of both dust and odor as a feedlot problem. The IEPA, which handles these problems on a case-by-case citizen complaint basis, has brought two suits to enjoin and seek penalties from poultry operations which were causing odor problems.

ADDRESS: Illinois Environmental Protection Agency
Division of Air Pollution Control
2200 Churchill Road
Springfield, Illinois 62706
217/782-3397

NUISANCE

All municipalities have the authority to define, prevent and abate nuisances (11-60-2). There is no express county authority to abate nuisances, but counties may regulate air contamination which would include odors (34-421.2).

INDIANA

Key to Legal Citation
Ind. Code §____
(§____)
(13-7-2-9)

AIR

The Environmental Management Board (EMB) and the Air Pollution Control Board (APCB) are jointly responsible for implementing the state's air pollution program (13-7-2-9). Air pollutants are defined by one statute to include odors (13-7-1-2), but in the statute creating the APCB, the definition of air contaminants makes no mention of odors (13-1-1-2). EMB is encouraged to aid local bodies in developing programs to provide odor pollution control (13-7-3-1). In preparing abatement orders, the APCB must take into consideration the social and economic value of the activity causing the emissions and the feasibility of installing a control device (13-1-1-4). Otherwise, the basic regulatory device is a permit requirement for all air pollution sources (13-7-10-1). In addition to the APCB, certain urban counties and all large cities have the authority to regulate sources of air pollution, including odor sources, within their jurisdiction (18-4-21-2, 18-1-1.5-12). The APCB-promulgated regulations define air pollutants without mentioning odors, although odor is contained in one of the two relevant state statutes.

ADDRESS: Air Pollution Control Board
1330 W. Michigan Street
Indianapolis, Indiana 46206
317/633-4273

NUISANCE

Nuisances are broadly defined by statute (34-1-52-1). Nuisances can be abated or enjoined by anyone (34-1-52-3). The keeping of any animal which may lead to noisome smells is a public nuisance (35-1-102-2).

IOWA

Key to Legal Citation
Iowa Code (§____)
(455B.12)

AIR

The Department of Environmental Quality (DEQ) and the Air Quality Commission are the agencies responsible for implementing the state's air pollution program (455B.12). Air contaminants are defined to include dust and odorous substances (455B.10). Existing regulations define an objectionable odor as one which is believed to be objectionable by 30% or more of a random sample of people. DEQ has recently amended its odor regulations. The definition of objectionable odor has been replaced by the use of three new terms: odor, odorous substance and odorous substance source. No attempt is made to quantify odor. These definitions become effective January 1, 1978. Special requirements are made for users of anaerobic lagoons. They must seek DEQ permits and provide on the application forms the animal capacity, type of animal, method of feeding and methods of waste collection and disposal. Equipment used on farms or ranches for agricultural purposes, except for anaerobic lagoons, is exempt from the permit requirements. These regulations are also to become effective on January 1, 1978. The following regulations, governing specific odorous substances, will not become effective until January 1, 1979. There is a general proscription against the emission of an odorous substance so as to create a nuisance. An exception is made for the periodic spreading of animal manure on farmland if reasonable care is taken to minimize odor problems. Recommended practices include immediate soil incorporation, proper site location, and proper climatic conditions. Reference is given to the land application guidelines of the Water Quality Division. Odor complaints may be filed with either the local board of health or DEQ. The complaint must be filed by 3 or more citizens, from different occupied premises within 5 miles of the source, who allege that the odor has occurred on at least 10 days of any 30-day period. DEQ must investigate the complaint; if it finds the complaint valid and if negotiations fail, DEQ must issue a notice of violation. New feedlots large enough to require a water permit must also seek a permit from the Air Quality Commission after submitting to DEQ the plans and specifications for the proposed facility.

ADDRESS: Department of Environmental Quality
Air Quality Management Division
3920 Delaware Avenue
P. O. Box 3326
Des Moines, Iowa 50316
515/265-8134

NUISANCE

State, county and municipal boards of health have the primary responsibility over public health matters including the right to issue permits for the collection and disposal of solid wastes (137.7). Local boards are involved in the air pollution regulatory scheme dealing with odor complaints. They also have the power to abate nuisances which are broadly defined by statute (657.1).

MISCELLANEOUS

An important new law was enacted by the Iowa legislature in 1976 with an avowed purpose of protecting the feedlot operator. Compliance with the statutory requirements by a feedlot operator is an absolute defense to a nuisance action if the person complaining did not own the affected realty prior to the "established date of operation" of the feedlot (172D.2). Compliance with applicable DEQ and U.S. EPA rules is mandatory if the rules were promulgated prior to July 1, 1975 (172D.3). DEQ rules affecting air quality adopted prior to November 1, 1976, apply to every feedlot regardless of its established date of operation. All air quality rules relating to feedlot management standards adopted after November 1, 1976, do not apply to pre-existing feedlots for a period of one year after the effective date of the rule. Rules relating to feedlot design standards adopted after November 1, 1976, do not apply to a pre-existing feedlot for a period of 10 years from the established date of operation of the feedlot or of two years from the effective date of the rule, whichever is greater (172D.3). All other DEQ rules in effect prior to November 1, 1976, also apply to all pre-existing feedlot operations. Rules adopted after November 1, 1976, do not apply to feedlots with existing DEQ permits for a period of 10 years from the established date of operation or 5 years from the effective date of the rule, whichever is greater (172D.3). A rule adopted after November 1, 1976, that affects a feedlot which previously was not required to get a DEQ permit has a similar grace period (172D.3). Zoning ordinances apply to feedlots where the ordinance predates the feedlot. Zoning ordinances, other than municipal, adopted after the established date of operation do not apply for a period of 10 years from enactment. A city zoning ordinance enacted prior to November 1, 1976, applies to all feedlots. A city zoning ordinance does not apply to a feedlot which has been annexed or incorporated into the city after November 1, 1976, for a period of 10 years from the acquisition of jurisdiction by the city (172D.4).

KANSAS

Key to Legal Citation
Kan. Stat. §____
(§____)
(65-3002)

AIR

The Department of Health and Environment (DHE) is the agency responsible for implementing the state's air pollution control program (65-3002). Air contaminants are defined to include odorous substances and dust (65-3002). Although there have been numerous odor-related complaints from residents living near feedlots, DHE has not adopted odor control regulations. The Air Quality Division usually refers odor complaints to the Bureau of Water Quality.

ADDRESS: Department of Health and Environment
Forbes AFB Bldg. No. 740
Topeka, Kansas 66620
913/296-3821

NUISANCE

DHE has the primary responsibility for abating nuisances (65-159). That power may be delegated to local boards of health as well (65-159). By regulation, the collection or accumulation of animal excrement or offal that can become a breeding place for insects is a nuisance (Reg. 28-5-4). DHE solid waste regulations broadly define nuisance in terms of the storage, handling and disposal of solid waste.

KENTUCKY

Key to Legal Citation
Ky. Rev. Stat. §____
(§____)
(224.005)

AIR

The Department of Natural Resources and Environmental Protection (DNREP) is responsible for implementing the air pollution program (224.005). The Division of Air Pollution Control within DNREP has primary authority. Air contaminant is defined to include odors. There are two regulations that are generally applicable to feedlot operations, one being an odor regulation and the other a fugitive dust emissions limitation. The odor regulation requires that the odor not be detectable at equal to or greater than 7 dilutions on a Barnebey-Cheney Scentometer at the property line (401 KAR 8:020). It is to be enforced if a homestead nuisance situation is proven. DNREP may exercise concurrent abatement powers with local air pollution control districts if it certifies that their program meets the minimum standards created by the state (224.450). The program may be operated by either cities or counties. The statute specifies an opacity limitation (77.155), but exempts equipment used for agricultural operations in the growing of crops or the raising of fowl or animals (77.160). Likewise, the local permitting requirements are waived for equipment used in agricultural operations (77.195).

ADDRESS: Department of Natural Resources and
Environmental Protection
Division of Air Pollution Control
275 East Main Street
Frankfort, Kentucky 40601
502/564-3382

NUISANCE

The Department of Human Resources has the authority to abate all nuisances within the state (211.210). Every property owner in cities has a duty not to allow his property to become a public nuisance (381.770). Both city and county health boards also have the power to abate nuisances (212.245). Large cities may also prohibit, remove or regulate the erection or maintenance of any stockyard, slaughterhouse, pigpen, cow stable, or dairies within city limits and up to two miles outside of city limits (84.220). Smaller cities have only one mile extraterritorial jurisdiction for nuisance abatement (85.180).

LOUISIANA

Key to Legal Citation
La. Rev. Stat. Ann. §____ (West)
(§____)
(40:2202)

AIR

The Air Control Commission (ACC) is the agency responsible for implementing the state's air pollution program (40:2202). Odors are not specifically mentioned in the definition of an air contaminant (40:2202). There appears to be a conflict between the authority of Health and Human Resources Administration (HHRA) to promulgate odor regulations and the statutory exclusion of all regulation of air contaminants other than by the ACC with the sole exception of private actions to abate nuisances (40:2216). HHRA handles odor complaints on a case-by-case basis, regardless of the apparent conflict with the ACC's authority over air contaminants (40.2216). ACC has not enacted any odor-related regulations.

ADDRESS: Air Control Commission
P. O. Box 60630
New Orleans, Louisiana 70130
504/568-5521

NUISANCE

HHRA is given authority to control and abate nuisances within the state (40:11). Both parish (county) and local boards of health may administer to all matters of local sanitation, including nuisance abatement (40:35). Cities and towns may also abate nuisances which are defined to include hog pens, slaughterhouses or stockyards (33:401). The local boards of health may also prescribe regulations for cleaning these facilities and for their location within the town (33:401).

MAINE

Key to Legal Citation
Me. Rev. Stat. Tit.____, §____
(Tit.____-§____)
(38-582)

AIR

The Department of Environmental Protection (DEP) is responsible for administering the state's air pollution program (38-582). Odor is not specifically mentioned in the definition of air contaminant (38-582). Animal wastes are defined as a type 4 waste (38-582). There are no specific regulations applicable to feedlots, but there is a general prohibition against the discharge of air contaminants, which would apply to the feedlot operator (38-591). Local governments may adopt more stringent air pollution regulations (38-597). Air pollution and air contaminant are defined broadly enough to include odors and fugitive dust (38-582). Animal excreta are included within the definition of waste for air pollution purposes (38-582).

ADDRESS: Department of Environmental Protection
Bureau of Air Quality Control
State House
Augusta, Maine 04333
207/289-2431

NUISANCE

Nuisances are defined very broadly, and include the causing of a noisome substance to collect to the detriment of another (17-2802). The Department of Human Services is given the responsibility of abating nuisances (22-1). Placing of manure in a local dump without permission of the city health officer is specifically prohibited (30-4102).

MARYLAND

Key to Legal Citation
Md. Ann. Code Art.____, §____
(Art.____-§____)
(43-690)

AIR

The Department of Health and Mental Hygiene (DHMH) has sole jurisdiction over the air pollution program (43-690). The definition of air pollution includes the emission of odors (43-691). The primary regulatory tool is a permit system for all sources of emissions (43-706). Cities and counties have the authority to adopt more stringent standards (43-705). No odor or fugitive dust regulations have been enacted by DHMH.

ADDRESS: Department of Health and Mental Hygiene
Bureau of Air Quality Control
610 North Howard Street
Baltimore, Maryland 21201
301/383-2779

NUISANCE

DHMH has the primary authority to set regulations dealing with nuisance-type activities (43-1F). City boards of health may abate nuisances within city limits (43-47). Local boards are given special abatement powers over privy pits, pigpens and other installations that occur within city limits (43-49). Towns or villages, even if without local health departments, may make rules and regulations dealing with pigpens or other noxious places that may create a nuisance (43-103).

MASSACHUSETTS

Key to Legal Citation
Mass. Gen. Laws Ann. Ch____, §____(West)
(Ch____-§____)
(111-2)

AIR

There appears to be a dual system of regulation of air pollution at the state level: one by the Department of Public Health (DPH) and the other by the Department of Environmental Quality Engineering (DEQE)

(111-2). Air pollutants are defined to include odor (111-2B). DEQE may adopt regulations dealing with atmospheric pollution (11-142A). By regulation, all emissions of air contaminants causing air pollution are prohibited. No person, including agricultural operations, may permit emissions which cause or contribute to air pollution by allowing odors or fugitive dust to escape. This regulation is enforceable by local police, fire departments, local boards of health, or building inspectors. Local and metropolitan air pollution control districts may also be created (111-142C-D). Local boards of health also have air pollution jurisdiction, including odor abatement powers (111-31C).

ADDRESS: Department of Environmental Quality Engineering
Bureau of Air Use Management
600 Washington Street
Boston, Massachusetts 02111
617/727-5194

NUISANCE

The state DPH is the major agency responsible for nuisance-type activities (111-5). Departmental investigators must report to the Director of Animal Health all barns, stables or other enclosures which are not kept in a sanitary condition (111-16). Boards of health in any city or town, provided they hold a public hearing, may regulate the location of noisome trades, including those that are attended by injurious odors (111-143). DEQE may act as an appeal board from a local determination (111-143). Local boards of health have the power to license stables and regulate their location in cities of over 5,000 (111-155). Local boards of health have both inspection and regulation power as to nuisances (111-122). Private suits to enjoin nuisances are specifically provided for (111-134).

MICHIGAN

Key to Legal Citation
Mich. Comp. Laws §____
(§____)
(336.13)

AIR

The Department of Natural Resources (DNR) and the Air Pollution Control Commission (APCC) are the agencies responsible for implementing the state's air pollution program (336.13). Air pollution is specifically defined to exclude the "usual and ordinary animal odors associated with agricultural pursuits and located in a zoned agricultural area if the numbers of animals and methods of operation are in keeping with normal and traditional animal husbandry practices for the area" (336.12). Some feedlots may not qualify for the exemption and, therefore, would be subject to the general nuisance definition of air pollution contained in the regulations (Reg. 336.46). There are no fugitive dust or odor regulations.

ADDRESS: Department of Natural Resources
Air Quality Division
Stevens T. Mason Bldg.
Lansing, Michigan 48926
517/373-8630

NUISANCE

County boards of health have the primary responsibility to abate nuisances (14.166).

MINNESOTA

Key to Legal Citation
Minn. Stat. Ann. §____(West)
(§____)
(116.02)

AIR

The air pollution program is operated by the Minnesota Pollution Control Agency (PCA) (116.02). Air contaminants are defined to include dust and gases; there is no explicit mention of odors (116.06). The PCA has enacted odor control rules (APCA). No person may permit the emission of odorous air pollution in excess of the given standards. No odor source of less than 50 feet in elevation may emit more than 25 odor concentration units (OCU). An OCU is defined to be the number of standard cubic meters of odor-free air needed to dilute each cubic meter of contaminated air so that at least 50% of the test panel does not detect any odor. Emissions beyond the property line are limited to 1 OCU in a residential or recreational zone, 2 OCU's in light industrial zones, and 4 OCU's in all other districts. The odor of growing vegetation is not considered to be odorous air pollution. The use of fertilizer is odorous air pollution. Compliance with the provisions of this regulation does not exempt the landowner from a public or private nuisance action.

ADDRESS: Pollution Control Agency
Division of Air Quality
1935 West County Road B2
Roseville, Minnesota 55113
612/296-7331

NUISANCE

The State Board of Health establishes and enforces health standards and identifies environmental health hazards (144.05). Public nuisances are broadly defined by statute (609.74). Any person is given the right to file a civil action for damages, injunctive relief or both to abate a nuisance (561.01). State or county boards of health also have the power to abate nuisances, including premises where noisome odors may arise (145.17).

MISCELLANEOUS

Minnesota allows all individuals to seek legal relief for environmental injuries (116B.01). However, there is an exemption for family farms, family farm corporations and bona fide farmer corporations (116B.02). Pollution for which civil action may be filed is defined so as to exclude injury caused solely by the presence of odors in the air (116.02). State Environmental Impact Statements (EIS's) are required for all state activities, including the issuance of water pollution, air pollution and solid waste permits (116D.04).

MISSISSIPPI

Key to Legal Citation
Miss. Code Ann §____
(§____)
(49-17-3)

AIR

The Air and Water Pollution Control Commission (AWPCC) is the agency responsible for implementing the state's air pollution program (49-17-3). Dust, but not odor, is listed as an air contaminant (49-17-5). Odor and dust arising from buildings or equipment are also prohibited if they would cause a nuisance.

ADDRESS: Air and Water Pollution Control Commission
Division of Air Pollution Control
P. O. Box 827
Robert E. Lee Building
Jackson, Mississippi 39205
601/354-6783

NUISANCE

The State Board of Health and local boards are delegated general authority to abate nuisances caused by unsanitary conditions (41-3-15). Local governments are also given the power to make regulations to prevent, remove and abate nuisances (21-19-1). Hogpens, slaughterhouses, stockyards, stables and other places where offensive matter can be accumulated are specifically singled out for local control (21-19-1).

MISSOURI

Key to Legal Citation
Mo. Ann. Stat. §____(Vernon)
(§____)
(203.040)

AIR

The Air Conservation Commission (ACC) and the Department of Natural Resources (DNR) are responsible for implementing the state's air pollution program (203.040). The statute, in defining air contaminant and air pollution, does not mention odors (203.020). The ACC has enacted a regulation, applicable in most Missouri counties, which restricts the emission of odors so as not to exceed 7 dilutions on a scentometer, conducted in two separate tests within a 1-hour period (Reg. S-IX). The regulation is considered to be a nuisance-type regulation and is enforced only upon the receipt of citizen complaints.

ADDRESS: Department of Natural Resources
Air Quality Program
117 Commerce Drive
P. O. Box 1368
Jefferson City, Missouri 65101
314/751-3252

NUISANCE

All public nuisances may be abated by court action, even though the use is not specifically listed in the statute as being a nuisance (564.080). Cities have the power to abate nuisances by legislative actions and to impose the cost of abatement on the property owner (71.780). Smaller cities may by ordinance regulate or abate stockyards, pigpens, cow stables, dairies and the like (77.560, 79.370).

MONTANA

Key to Legal Citation
Mont. Rev. Codes Ann. §____
(§____)
(69-3906)

AIR

The Department of Health and Environmental Sciences (DHES), Air Quality Bureau regulates the state's air pollution program (69-3906). The definitions of air contaminants and air pollution specifically include odorous substances (69-3906). The guidelines for new feedlots specifically recommend that potential odor problems be considered in site selection. As a rule of thumb, feedlots should be located at least two miles from residences and 5-6 miles from municipalities. Odor control by minimum handling of the manure and by keeping it dry is recommended. Spreading should be done when atmospheric conditions are best suited for minimal air pollution effects. The regulations prohibit the emission of odors which would create a public nuisance beyond one's property line. Odor producing materials should be stored and handled so as not to create a public nuisance.

ADDRESS: Department of Health and Environmental Sciences
Air Quality Bureau
Cogswell Building
Helena, Montana 59601
406/449-3454

NUISANCE

DHES is given general responsibility to control nuisances (69-4110). It may also delegate that authority to local boards of health (69-4509). Cities and towns also have nuisance abatement authority (11-935). Nuisances are broadly defined by statute (57-101). Nuisances may be publicly or privately abated (93-6101, 94-8-107).

NEBRASKA

Key to Legal Citation
Neb. Rev. Stat. §____
(§____)
(81-1502)

AIR

The Department of Environmental Control (DEC) and the Environmental Control Council (ECC) have regulatory authority over the air pollution program. Although the definition of air pollution is broad enough to include odors, air contaminant is defined to include dust or gas but not odor (81-1502). The ECC requires the operator to drain waste runoff to a holding pond as soon as possible to insure that the lot surface remains aerobic. Where solids are separated from the liquid, adequate time for settling must be provided before draining the runoff water to a holding pond (Rule 20). The Extension Service recommends good management practices for manure and moisture to minimize feedlot-created odors.

ADDRESS: Department of Environmental Control
Air Pollution Control Division
Box 94653
Lincoln, Nebraska 68509
402/471-2186

NUISANCE

All counties, cities, towns and villages have a primary responsibility to abate nuisances (18-1720).

NEVADA

Key to Legal Citation
Nev. Rev. Stat. §____
(§____)
(445.421)

AIR

The State Environmental Commission (SEC) and the Department of Human Resources (DHR) are responsible for the air pollution program (445.421). Air contaminant is so defined as to include any substance except water discharged into the atmosphere (445.411). The basic regulatory system is a permit system (445.473). Local air pollution control programs may be established (445.546). Odor is so defined in the regulations as to include a characteristic of an air contaminant which makes it perceptible to the sense of smell (Reg. 1.43). Agricultural land use is exempted from the registration certificate and operating permit requirement for sources of air contaminants (Reg. 3.1.8). The odor regulation provides that the SEC shall investigate an odor when 30% or more of a sample of people exposed to it believe it to be objectionable. The source is in violation if two measurements taken 15 minutes apart, but within one hour, are such that the odor is still detectable after dilution with 8 or more volumes of odor-free air (Reg. 10.1).

ADDRESS: Department of Human Resources
Air Quality Office
1209 Johnson Street
Carson City, Nevada 89701
702/885-4670

NUISANCE

Private actions for nuisance abatement and damages are specifically allowed by statute (40.140). Private citizens may also sue to enforce the environmental statutes of the state (41.540). The State Board of Health division of DHR has authority to regulate and prevent nuisances (439.200). Local boards of health also have nuisance abatement authority (439.360). Counties may enact sanitary ordinances if they are not in conflict with state laws (244.357). Counties must hold public hearings when a nuisance complaint is filed in the county clerk's office (244.360). County boards and city councils may also regulate air pollution, including odor problems (244.361, 268.410). City councils may regulate nuisances and provide that the abatement costs be recaptured from the nuisance owner (266.335).

NEW HAMPSHIRE

Key to Legal Citation
N.H. Rev. Stat. Ann. §____
(§____)
(125:80)

AIR

The Department of Health and Welfare (DHW) and the Air Pollution Control Agency (APCA) are responsible for implementing the state's air pollution program (125:80). Air contaminant is so defined as to specifically include odors (125:79). There are no odor of fugitive dust regulations.

ADDRESS: Air Pollution Control Agency
State Laboratory Building
Hazen Drive
Concord, New Hampshire 03301
603/271-2281

NUISANCE

DHW has overall state responsibility for public health and sanitation (125:9). City health officers may make regulations preventing and abating nuisances (147:1). No pigsty or pen may be erected in such a place or under such conditions that, in the judgement of the local health officer, it would be a nuisance (147:10). City and town councils may regulate nuisances, including the location and construction of slaughterhouses, stables, barns and other unwholesome buildings or places (47: 17).

NEW JERSEY

Key to Legal Citation
N.J. Stat. Ann. §____(West)
(§____)
(13:1D-7)

AIR

The Department of Environmental Protection (DEP), in conjunction with the Clean Air Council, is responsible for implementing the air pollution program (13:1D-7). While the definitions of air pollution and air contaminant do not refer to odors, in a court opinion odor was deemed to be an air contaminant within the purview of the definition of air pollution [Department of Health v. Owens-Corning Fiberglas Corp., 242 A.2d 21, aff'd 250 A.2d 11 (1968)]. DEP has overall authority to enforce its own rules and regulations dealing with air pollution. It has deferred its rule-making authority over agricultural operations to the Department of Agriculture. There are no odor or fugitive dust regulations except in the context of incinerator emission standards.

ADDRESS: Department of Environmental Protection
Bureau of Air Pollution Control
P. O. Box 2807
Trenton, New Jersey 08625
609/292-6704

NUISANCE

All buildings or places where the law (including the sanitary code) is violated are considered to be nuisances (2A:130-2). A nuisance may be abated immediately (2A:130-4). Cities of the 4th class have the power to abate nuisances and charge the cost to the owner (40:173-8). Local boards may also define nuisances (26:3-45) and ordor abatement (26:3-46). Cities may regulate or prohibit the keeping of cattle, goats or swine in any part of the municipality (40:48-1).

NEW MEXICO

Key to Legal Citation
N.M. Stat. Ann. §____
(§____)
(12-14-3)

AIR

The Environmental Improvement Agency (EIA) and the Environmental Improvement Board (EIB) are jointly responsible for implementing the state's air pollution program (12-14-3). The definitions of air contaminant and air pollution do not specifically include odors (12-14-2). The EIB has not enacted any odor or fugitive dust regulations.

ADDRESS: Environmental Improvement Agency
Air Quality Division
P. O. Box 2348
Santa Fe, New Mexico 87503
505/827-2813

NUISANCE

The Department of Health and Social Services has primary responsibility to abate nuisances (12-34-3). Municipalities may by ordinance define and abate all nuisances (14-17-14).

NEW YORK

Key to Legal Citation
N.Y. [Subject] Law §____ (McKinney)
(Subject Law §____)
(Environmental Conservation Law 3-0301)

AIR

The Department of Environmental Conservation (DEC) is the agency responsible for implementing the state air pollution abatement program (ECL 3-0301). Air contaminanat is defined to include dust and odor (ECL 19-0107). The Guidelines suggest that ventilating systems in buildings used to house animals, manure storage systems, manure dehydration systems, fields where manure is spread and incinerators of dead animals would all be sources of air contaminants required to obtain permits under the statute (ECL 19-0107). In the regulations there is no exemption for any of these agriculturally-related operations from the permit requirement (Part 201). Under Part 211, no person shall allow air pollution as defined by the statute. This could include agricultural sources. Manure dehydrating systems come under Part 212, which requires a permit to construct and a certificate to operate an exhaust or ventilation system. Qualified air pollution control facilities are exempt from real property tax to the extent of the increase in the value of the operation. There are no odor-related regulations except those concerning the operation of incinerators.

ADDRESS: Department of Environmental Conservation
Division of Air Resources
50 Wolf Road
Albany, New York 12233
518/457-7231

NUISANCE

The Commissioner of Public Health, on the state level, is possessed with all of the necessary powers to investigate and abate nuisances (Public Health 1300). Local boards of health also have the authority to investigate and abate nuisances (Public Health 1303). Cities have general nuisance abatement powers, including the ability to license certain businesses (General City 20). Towns may regulate unnecessary emissions of smoke or noxious gas and may regulate the keeping of livestock (Town 130).

NORTH CAROLINA

Key to Legal Citation
N.C. Gen. Stat. Ann. §____
(§____)
(143-215)

AIR

The Department of Natural and Economic Resources (DNER) and the Environmental Management Commission (EMC) are responsible for implementing the state's air pollution program (143-215.106). Air contaminant is defined so as to include dust but does not specifically mention odors (143-213). The regulatory system is basically a permitting operation (143-215.108). EMC has promulgated regulations dealing with odorous emissions. Although one part of the regulation states that the regulation applies to all sources of odorous emissions, the other section deals only with controlling odorous emissions from a plant engaged in the processing of animal matter. EMC has the power to transfer to counties or cities responsibility for local air pollution control programs (143-215.112).

ADDRESS: Department of Natural and Economic Resources
Division of Environmental Management
Air Quality Section
P. O. Box 27687
Raleigh, North Carolina 27611
919/829-4740

NUISANCE

Local boards of health are given the primary responsibility to abate nuisances (130-20). Cities may also abate nuisances both within city limits and up to one mile outside of the city (160S-193).

NORTH DAKOTA

Key to Legal Citation
N.D. Cont. Code §____
(§____)
(23-25-03)

AIR

The Department of Health (DOH) is responsible for implementing the air pollution abatement program (23-25-03). There is, in addition, a State Air Pollution Control Agency which is an advisory council; there are no agricultural representatives on it (23-25-02). By a recent amendment to the law, air contaminants are defined to include odorous substances (23-25-01). The basic regulatory scheme is a permit system with the right of on-site inspection (23-25-05). The regulations prohibit the emission of any air contaminant that may cause a public nuisance. Odor regulations are being drafted for review in September 1977. At the present time DOH uses informal and formal hearings to prevent odor problems on a case-by-case basis.

ADDRESS: Department of Health
Division of Environmental Engineering
1200 Missouri Blvd.
Bismarck, North Dakota 58501
701/224-2374

NUISANCE

Both city and county boards of health have the authority to inquire into all nuisances and to seek abatement if, in fact, a nuisance is found (23-05-01, 23-05-04). Nuisances are broadly defined by statute (42-01-01).

OHIO

Key to Legal Citation
Ohio Rev. Code Ann. §____ (Page)
(§____)
(3704.03)

AIR

The Ohio Environmental Protection Agency (OEPA) is responsible for implementing the air pollution program (3704.03). Air contaminants are broadly defined to include dust and odorous substances (3704.01). The regulations prohibit the emission of fugitive dust or odors that would constitute a nuisance.

ADDRESS: Ohio Environmental Protection Agency
P. O. Box 1049
361 East Broad Street
Columbus, Ohio 43216
614/466-8565

NUISANCE

City and county boards of health may abate all public nuisances (3707.01). They may also regulate the location, construction and repair of yards, pens and stables (3707.01).

OKLAHOMA

Key to Legal Citation
Okla. Stat. Ann. tit____, §____(West)
(tit____, §____)
(63-2002)

AIR

The Department of Health (DOH) and an advisory Air Quality Council (AQC) are jointly responsible for implementing the state's air pollution program (63-2002). The definition of air contaminants does not include odors (63-2002). Cities and towns are not precluded from enacting ordinances with respect to air pollution that are not in conflict with the state law, or from enacting ordinances dealing with public nuisances (63-2004). The Oklahoma Clean Air Act does not authorize DOH to limit, modify or in any way affect the powers, duties or functions of the State Board of Agriculture.

ADDRESS: Department of Health
Air Quality Service
Northeast 10th & Stonewall Streets
Oklahoma City, Oklahoma 73105
405/271-5220

NUISANCE

Nuisances are broadly defined by statute to include anything that annoys, injures or endangers the comfort, repose, health or safety of others (50-1). Nothing which is done under the express authority of a statute may be deemed to be a nuisance (50-4). Therefore, feedlots which operate under a State Board permit may not be declared to be nuisances if they meet the requirements of operation contained in the regulations (50-4). All nuisances may be abated or, in the case of a public nuisance, there may be a criminal prosecution(50-8).

OREGON

Key to Legal Citation
Ore. Rev. Stat. §____
(§____)
(468.275)

AIR

The Department of Environmental Quality (DEQ) is responsible for implementing the air pollution program (468.275). Air contaminants and air pollution are defined to include both fugitive dust and odors (468.275).

ADDRESS: Department of Environmental Quality
Air Quality Division
1234 S.W. Morrison Street
Portland, Oregon 97205
503/229-5749

NUISANCE

Both the State Board of Health and local boards have the authority to abate nuisances which are threats to the public health (431.140).

PENNSYLVANIA

Key to Legal Citation
Pa. Stat. Ann. tit____, §____ (Purdon)
(tit____ §____)
(35-4003)

AIR

The Department of Environmental Resources (DER) and the Environmental Quality Board (EQB) are the agencies responsible for implementing the state's air pollution program (35-4003). Air contaminant is defined to specifically include odors (35-4003). All new sources of air pollution are required to obtain permits (35-4006.1). DER has not enacted any odor regulations. The DER, however, is not authorized to interfere if a local air pollution control agency has been approved. In addition, local governments may enact their own ordinances dealing with air pollution as long as they are not less stringent than the state rules (35-4012).

ADDRESS: Department of Environmental Resources
Bureau of Air Quality Control
Harrisburg, Pennsylvania 17120
717/787-9702

NUISANCE

On the state level the DER has the power to declare unsanitary conditions to be public nuisances (71-510-17). Counties have relatively significant nuisance abatement powers through the County Health Department (16-12026). Counties have powers only in the unincorporated and non-township areas (16-12013). Township sanitary boards also have the authority to inspect for and abate nuisances, including hog pens, stables and stableyards (53-66958). First-class townships may regulate manure pits, slaughterhouses and pigpens to prohibit or to remove any noxious business (53-56526). Boroughs have the authority to regulate the accumulation of manure, compost and the like, as well as to prohibit the keeping of hogs or other livestock within their boundaries (53-46202). Boroughs may also abate nuisances (53-10608). First-class cities may regulate stables for all stock but cattle, including the transportation and storage of manure (53-14451-14452).

RHODE ISLAND

Key to Legal Citation
R.I. Gen. Laws §____
(§____)
(23-25-5)

AIR

The Department of Health (DOH) is responsible for implementing the state's air pollution program (23-25-5). There is also a State Air Pollution Advisory Board (23-25-4). Air contaminant is defined to include odors (23-25-3). There are no odor emission regulations.

ADDRESS: Department of Health
Division of Air Pollution Control
75 Davis Street
Providence, Rhode Island 02908
401/277-2808

NUISANCE

The attorney general or any citizen of the state may file an action in the name of the state seeking to abate any nuisance conditions (10-1-1). Cities and towns may regulate the location and maintenance of all places for keeping animals and may enact rules and regulations dealing with the time and manner of removing manure therefrom (23-19-1).

SOUTH CAROLINA

Key to Legal Citation
S.C. Code §____
(§____)
(63-195.7)

AIR

The Department of Health and Environmental Control (DHEC), Pollution Control Authority (PCA) is given primary responsibility for implementing the air pollution control program (63-195.7). Although the regulatory system is primarily a permitting system, there have been no attempts to promulgate regulations dealing with the feedlot type operation (63-195.14). Air contaminants are defined to include fugitive dust, but odors are not directly mentioned. There are no odor or fugitive dust regulations.

ADDRESS: Department of Health and Environmental Control
Bureau of Air Quality Control
2600 Bull Street
Columbia, South Carolina 29201
803/758-5496

NUISANCE

The State Board of Health has the primary responsibility for controlling and regulating nuisances (32-2). Local boards of health are supervised by the state (32-12). The State Board's activities do not, however, limit the right of any individual to bring an action to abate a nuisance (32-10). The State Board has promulgated regulations defining nuisances to include the feedlot type operation where excessive flies, rodents or other vectors are produced.

SOUTH DAKOTA

Key to Legal Citation
S.D. Compiled Laws Ann. §____
(§____)
(34-16A-2)

AIR

The Department of Environmental Protection (DEP) is the agency responsible for implementing the air pollution program (34-16A-2). Air contaminants are specifically defined to include odorous substances and particulate matter (34-16A-2). A permit system is created for new sources (34-16A-21). Regulatory powers are delegable to municipal and county agencies (34-16A-41). DEP regulations prescribe the procedure to be followed for abating odorous emissions. If five or more complaints are received, DEP must investigate. The odor is deemed to be objectionable only if a majority of the members of a five-person panel determine that the odor tends to be unreasonably injurious to human health or welfare. The emitter must take all reasonable steps, as required by DEP, to control the objectionable odor.

ADDRESS: Department of Environmental Protection
Joe Foss Building
Pierre, South Dakota 57501
605/224-3351

NUISANCE

The State Public Health Advisory Committee has authority to control public nuisances and sewage disposal (34-1-17). This power is shared with municipalities(9-29-13). Cities may abate nuisances up to one mile outside the city limits (9-29-1).

TENNESSEE

Key to Legal Citation
Tenn. Code Ann. §____
(§____)
(53-4309)

AIR

The Department of Public Health (DPH) is responsible for implementing the state's air pollution program (53-4309). The definition of air contaminants does not specifically include odors (53-4309).

ADDRESS: Department of Public Health
Division of Air Pollution Control
Cordell Hull Building
Nashville, Tennessee 37219
615/741-3931

NUISANCE

Nuisances are broadly defined by statute (39-2903). Nuisances may be abated by court action (39-2902).

TEXAS

Key to Legal Citation
Tex. Rev. Civ. Stat. Ann. art____
(art____)
(4477-5)

AIR

The Texas Air Control Board (TACB) is the agency responsible for implementing the air pollution program (4477-5). Air contaminant is defined by statute to include both particulate matter and odor (4477-5). The TACB grants construction and operating permits for new sources of air contaminants (4477-5). The regulations provide that no person shall discharge from any source one or more air contaminants that may tend to be injurious to, or adversely affect human health or welfare, animal life, vegetation or property (Rule 5). Under TACB Regulation VI, all new facilities that may emit air contaminants must submit their plans for approval and permit receipt. TACB also requires the facility to utilize best available control technology, giving consideration to economic and technical factors to reduce or eliminate the emissions, including odor, resulting from the facility (Rule 603.16).

ADDRESS: Texas Air Control Board
8520 Shoal Creek Blvd.
Austin, Texas 78758
512/451-5711

NUISANCE

In counties with a population in excess of 525,000, the maintenance of feedlots or slaughterhouses within 500 feet of an established cemetery is declared to be a nuisance (930a-1). The state sets minimum standards for sanitation and health protection and broadly defines "nuisance" (4477-1). Local health officials may abate nuisances (4477-1). No waste product or offal may be stored so as to cause either land or water pollution (4477-1). Cities may regulate the depositing of offensive substances within their jurisdiction and may compel the owner of a stable, slaughterhouse or other unwholesome establishment to clean, remove or abate the same (1015).

UTAH

Key to Legal Citation
Utah Code Ann. §____
(§____)
(26-24-5)

AIR

The Division of Health (DOH) and the Air Conservation Committee (ACC) are responsible for implementing the state's air pollution program (26-24-5). Membership on the ACC is earmarked for representatives of various industries including one representative from the agricultural area (26-24-4). Odor is not included in the definition of an air pollutant (26-24-2). There are no odor or fugitive dust regulations.

ADDRESS: Department of Social Services
Division of Health
Bureau of Air Quality
44 Medical Drive
Salt Lake City, Utah 84113
801/328-6108

NUISANCE

Nuisances are broadly defined by statute (78-38-1). Odors may cause a nuisance situation to occur, as was declared in a case dealing with an animal rendering plant. The abatement of nuisances is entrusted to local boards of health (26-5-5). They are under the aegis of the State Division of Health (26-15-4).

VERMONT

Key to Legal Citation
Vt. Stat. Ann. tit____, §____
(tit____, §____)
(10-552)

AIR

The Agency for Environmental Conservation (AEC) is responsible for implementing the state's air pollution program (10-552). The definition of air contaminant includes odorous substances (10-552). The AEC has promulgated regulations dealing with the prohibition of nuisances and odor (Reg. 5-241). There is a blanket prohibition against the discharge of any emission of objectionable odors beyond one's property line (Reg. 5-241). No technique is specified for the measurement of the odors. The odor regulations are enforced solely on a citizen complaint basis.

ADDRESS: Agency for Environmental Conservation
Air Pollution Control Section
State Office Building
Montpelier, Vermont 05602

NUISANCE

Local health officials have the power to abate nuisances (9-610).

VIRGINIA

Key to Legal Citation
Va. Code §____
(§____)
(10-17.11)

AIR

The Air Pollution Control Board (APCB) is responsible for implementing the state's air pollution program (10-17.11). Although the statutory definition of air pollution does not specifically mention odor (10-17.10), there are regulations which prohibit the discharging of an odor which is objectionable to individuals of ordinary sensibility (Reg. 4.61). No measuring technique is mentioned; an odor panel survey is, however, one recommended method for determining whether the regulation has been violated. The APCB, in formulating relief from odor pollution facilities, must consider economic and technological feasibility (Reg. 4.62).

ADDRESS: Air Pollution Control Board
Room 1106
9th Street State Office Bldg.
Richmond, Virginia 23219
804/786-2378

NUISANCE

Cities and counties have the primary responsibility for abating nuisances. Counties may regulate the keeping of animals and fowl within a certain distance of residences (15.1-517). Cities have general authority to compel the abatement or removal of all nuisances (15.1-867). All nuisance actions must be brought before a special grand jury before abatement is possible (48-1).

WASHINGTON

Key to Legal Citation
Wash. Rev. Code §____
(§____)
(43.21A.060)

AIR

The Department of Ecology (DOE), Air Resource Division, is responsible for implementing the state's air pollution program (43.21A.060). Air pollution control authority may be delegated to local agencies consisting of one ore more cities and/or counties (70.94.053). Air contaminant is specifically defined to include any odorous substances (70.94.030). Under DOE regulations, every feedlot handling more than 1,000 animal units, and in some cases fewer, must register with DOE as an air contaminant source (WAC 18-04-040, WAC 18-04-100). The regulations call for registration of all cattle feedlots, but by administrative policy only the larger ones are required to seek permits. Local agencies have the option of imposing higher standards but may not fall below the minimum set by the state. The regulations call merely for the feedlot operator to observe good housekeeping and management practices to control the emission of dust and/or odor (WAC 18-04-040).

ADDRESS: Department of Ecology
Air Resource Division
Olympia, Washington 98504
206/753-2800

NUISANCE

Nuisances are broadly defined by statute (7.48.101). Several cases have found that odors are sufficiently injurious to neighboring landowners to become actionable nuisances.

WEST VIRGINIA

Key to Legal Citation
W. Va. Code §____
(§____)
(16-20-4)

AIR

The Air Pollution Control Commission (APCC), which includes the Commissioner of Agriculture as an ex officio member, is the ageny responsible for implementing the air pollution program (16-20-4). The definition of air pollutants does not specifically include odors (16-20-2). The water pollution regulations do, however, have an odor limit, which is defined to be a threshold odor number of 8 at 40 degrees centigrade (Reg. 7.01). The powers of the APCC do not diminish the powers of local or state health officials to reduce or abate air pollution. APCC regulations prohibit the emission of objectionable odors, which is to be defined by a representative of the APCC. The regulations recommend using the Barnabey-Cheney Scentometer or other recognized systems. An exception is made for the "normal and necessary" operations associated with the production of agricultural products or livestock or poultry raised on the premises.

ADDRESS: Air Pollution Control Commission
1558 Washington Street, East
Charleston, West Virginia 25311
304/348-3286

NUISANCE

All municipalities have the authority to prevent injury to their residents from anything that is offensive or unwholesome and to regulate or prohibit the keeping of animals or fowls within the city limits (8-12-5). The State Board of Health has general authority concurrent with local boards to abate nuisances (16-2A-1, 16-1-3).

WISCONSIN

Key to Legal Citation
Wis. Stat. Ann. §____(West)
(§____)
(144.30)

AIR

The Department of Natural Resources (DNR) is responsible for implementing the state's air pollution program. Air contaminants are defined to specifically include odorous substances (144.30). The regulations provide that no person shall cause or allow an emission that results in an objectionable odor unless preventive measures satisfactory to DNR are taken to control such an emission (Reg. NR 154.18). An objectionable odor is determined by either of two methods. The first is merely an investigation with findings made as to intensity, frequency and duration of odor, as well as to the type of area involved. The second test requires that 60% of a random sample of persons exposed to the odor claim it to be objectionable (Reg. NR 154.18). Abatement techniques recommended include removal and disposal of the odorous substance, changes in methods of handling and storage so as to minimize odor problems, and the following of prescribed standards in the maintenance of the premises. The statute provides for counties to adopt and administer local air pollution control programs, including regulation of emissions within the corporate boundaries of the cities contained within the counties (144.41).

ADDRESS: Department of Natural Resources
Air Quality Control Section
Box 7921
Madison, Wisconsin 53707
608/266-1199

NUISANCE

Any individual county, city, village or town may bring an action to abate a public nuisance (823.01). Violations of city ordinances may rise to the level of a nuisance and may be enjoined (823.07). Nuisances are broadly defined to include any source of filth (146.14). The cost of abating nuisance may be charged against the owner of the premises (146.14). Any city or village may restrict the location and construction or may license any industry which carries on a nauseous, offensive or unwholesome business within the corporate limits or within four miles outside its boundaries (66.052).

WYOMING

Key to Legal Citation
Wyo. Stat. §____
(§____)
(35-502)

AIR

The Department of Environmental Quality (DEQ), Air Quality Division (AQD), is the agency responsible for implementing the state's air pollution program (35-502.5). There is, in addition, an advisory board to AQD made up of five members, one of whom must represent agricultural interests (35.502.13). Air contaminants and air pollution are defined to include both dust and odors. AQD has issued regulations that specifically deal with the odor problem (Air Reg. Sect. 16). Odor emissions are measured at the property line and may be no greater than seven dilutions of odor-free air as measured on a scentometer. Two measurements must be taken within one hour before a violation is found. Odor producing materials must be stored so as to minimize odor emissions. Since it is an ambient air quality standard, all new or modified sources of odor must receive construction and operating permits issued by AQD.

ADDRESS: Department of Environmental Quality
Air Quality Division
State Office Building, West
Cheyenne, Wyoming 82002
307/777-7391

NUISANCE

The State Board of Health is given primary responsibility for abating nuisances (35-5).